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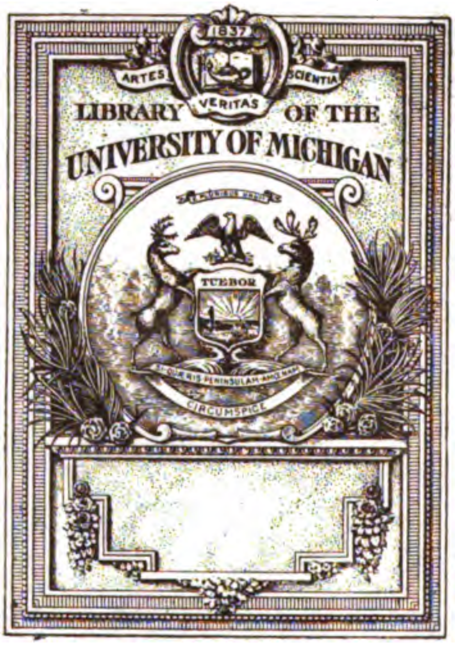
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Established 1897

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FORREST SHREVE

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A QUARTER-CENTURY OF GROWTH IN PLANT PHYSIOLOGY[1]

BURTON EDWARD LIVINGSTON

The Johns Hopkins University, Baltimore, Maryland

Introduction. The two and one-half decades during which the University of Chicago has achieved the remarkable development that we are here to celebrate, have witnessed a goodly number of notable changes in the status of botanical science in general, but I think no branch of that science has taken longer strides within this interval of time than has plant physiology. It appears that the continuation of this advance may be accelerated if we take some time, now and then, on such occasions as the present one, to pass in review what seem to be the lasting achievements of the past, and to face squarely what seem to be the general needs of the future. To study the happenings of the past as these may be related to one another, seems to offer the only known method upon which rational prediction may be founded, and the planning of future researches in our science must depend increasingly upon such prediction.

A period of popularization. The period in question has been characteristically one of the popularization of natural science in general, at least among the peoples that have been most active in scientific progress. Thanks to increasing education and to the printing of books and papers, the great principles and discoveries, and even much of the philosophy, of science have spread outward, from their sources in the minds of scientists, so that utter ignorance of these things is now comparatively rare, even among those who do not deal directly with science at all. Gravitation, magnetism, chemical reaction, evolution, the mineral nutrition of plants, fermentation by microorganisms—

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[1] Invitation paper read at the Botanical Session of the Quarter Centennial of the University of Chicago, June 6, 1916.

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these are terms now frequently heard among those who are not scientists, and often encountered in the daily press. Unknowingly, perhaps, the world is coming to look more and more to the scientists, for its utilities, for its amusements, and even for its philosophy and practical religion. Although physiology has been one of the last of the sciences to enter upon this phase of popularization, its progress in this direction has, nevertheless, been very rapid, especially since the closing years of the last century. On the animal side mainly through the arts of medicine and surgery, on the plant side mainly through those of agriculture and forestry, many of its elementary principles have become incorporated into general knowledge. The popularization of a knowledge of the mineral needs of plants, for example, has largely occurred in the period that we are considering.

This phase of plant physiological development, based largely on utilitarian desires, has made possible the establishment and rapid growth of many great institutions, such as the United States Department of Agriculture and numerous experiment stations throughout the world, and these, in turn, have furnished opportunity for the carrying out of an ever-increasing number of truly scientific researches on the dynamics of plant processes. There seems to be no limit to this kind of growth, and it is safe to predict that the next quarter-century will produce a still more general and clearer appreciation of both the utilitarian and the philosophical value of a knowledge of what plants do and how and why they do it. Anything that may advance this general appreciation should also hasten the development of the science itself.

Turning to the internal growth of physiology, I wish to mention first some alterations in general physiological philosophy that have become especially evident during these twenty-five years, and afterwards to direct your attention to a few of what appear to me as important forward steps in the special science of plant physiology.

Development of deterministic philosophy. Perhaps the most striking growth, or alteration, in physiological philosophy, to be detected by a comparison of the writings of the '70's and

'80's with those of the last decade, lies in the gradual development of a more and more thorough-going determinism. The echoes of an age-old struggle between mysticism, vitalism, and so forth, on the one hand, and mechanism or determinism, on the other, are still rolling on our scientific horizon, but the orderly quiet of physical science now extends into almost every phase of physiological thought. As Jacques Loeb has aptly remarked, no matter what may be the emotional attitude of a physiological investigator in these later days, such a one is sure to adopt a deterministic philosophy as soon as he steps into his laboratory and begins an experiment. What we may think or feel about questions that are too complex to be subjected as yet, to experiment, is of little consequence in modern science, but rational experimentation is practically impossible without the conviction that phenomena are rigidly determined by pre-existing conditions. While there may come other periods, as in times of great wars, when the stress of life itself may compel the temporary putting aside of reason, in favor of more elemental emotions, yet it may be safely predicted that physiological advancement will always be guided primarily by the mechanistic or deterministic conceptions that have come to us from the non-biological sciences. Progress has always been in this direction; as Cowles has said, many vitalistic interpretations have been replaced by mechanistic ones, but the reverse change has not yet occurred.

Tentative nature of physiological conclusions. In the twenty-five years here considered, physiology, along with other natural sciences, has undergone a marked alteration in respect to the final value that it places upon its interpretations. It is an interesting fact that increased knowledge of plant and animal processes has thus far tended rather to emphasize their extreme complexity than to establish their conditional relations in any final way. During the last quarter-century we seem, indeed, to have been mainly engaged in discovering new problems, rather than in solving the problems dealt with by earlier workers. In many cases the earlier problem has been analyzed into several component problems, each one of the latter appearing as difficult now as did the less thoroughly analyzed problem to the writers of a few decades ago. The physiology of the present day has largely to do with the application of physical and chemical principles and methods to the phenomena occurring in organisms, and this application necessitates the analysis of complex processes into their components, as far as this is possible.

Meanwhile, physical and chemical science have been advancing with rapid strides and have placed a whole world of precise quantitative knowledge in the hands of the physiologist, so that the latter now requires a far better acquaintance with the literature of the physical sciences than with that of plant and animal morphology. Progress has been so rapid and in so many widely different directions that there results, for the present, a sort of confusion, whereby the same phenomenon may be interpreted in widely different terms by different investigators. This state of affairs has led to a much more tentative attitude of mind among natural scientists in general, and especially among physiologists, than formerly prevailed. We have learned to state our conclusions tentatively, and as limited by certain suppositions, and we are not surprised if they require restatement within a few years. Nevertheless, we need not be discouraged, for progress clearly lies in just this continued reinterpretation and readjustment of our knowledge.

The outstanding fact, in this connection, seems to be that physiology deals with greater complexity than does any other natural science—since it has to do with the most complex materials and processes so far known to man—and the precise statement of physiological relations involves a far larger number of dependent variables, or arguments (in the mathematical sense), than are required in the other sciences. In spite of the great progress already made, we must regard physiology as a very youthful science and we must be content that it blunders and stumbles now and then as it moves forward.

Complexity of the printed records. One of the greatest changes to which science has been subjected in recent decades lies not so much in the complexity of the things dealt with as in the complexity of our records of scientific knowledge. Of the making of printed books there is no end, and each year sees the inauguration of new scientific journals. Physiological literature —and the literature of science in general—has become such an unwieldy mass that to investigate the records bearing upon any rather limited subject is now a staggering task in itself. Men have delved into nature, have brought forth the ore of experimental and observational results, have recovered the valuable metals as interpretations and conclusions, and have stored the latter in the great, hap-hazard store-house of the literature; and now it becomes almost as difficult to find out what is in the store-house and to utilize it as it is to obtain knowledge directly from nature by experimentation. Enormous, confused, hap-hazard, our literature is a veritable muddle, and much of our recorded knowledge will surely be hopelessly lost unless serious attention may soon be directed toward rendering its content practically available. Abstract or reviewing journals and yearbooks of various kinds are doing their best to help the student to obtain the references requisite for his work, but they are woefully inadequate, as every physiologist has learned too well. We require a means far more prompt and far more thorough than these, but the future alone can disclose just how such a means may be attained. I have wished here merely to emphasize this feature of recent physiological progress, whereby our science and the sciences related to it seem now tending to smother themselves by the accumulation of their own products.

Rise of general physiology. With the introduction of physical and chemical methods of experimentation and thinking, the two branches of physiology have been merging very rapidly, so that a true physiological science—of animals and plants together—seems already actually to have been formed. This change has occurred almost entirely within the last quarter-century; witness the fact that the first edition of Verworn's Allgemeine Physiologie appeared in 1894, that the first edition of Pfeffer's Pflanzenphysiologie appeared in 1880 and the second (almost entirely rewritten), in 1897. These works have done much toward bringing animal and plant physiology together and, at the same time, toward introducing chemical and physical conceptions. During the period here specially considered Verworn's book has undergone numerous revisions, and similar treatises by other authors have recently appeared. Pütter's Vergleichende Physiologie may be mentioned here, and, finally, the very best treatment of the general subject so far available has come from the hand of Bayliss, whose General Physiology was published only last year. From the first editions of Verworn and Pfeffer to Bayliss, is a long way for a science to progress in a quarter of a century, and these books may well serve as landmarks to indicate many aspects of our advance. I should also add that the publications of Jacques Loeb, together with the sometimes acrimonious but undoubtedly clarifying discussions that these have aroused, belong to this period. The writings of this author have been perhaps more influential than those of any other single worker, in the introduction of deterministic conceptions and in the unifying of physiology.

At any rate, we have now come generally to realize that the problems, and the methods by which they are to be attacked, are essentially the same, whether our subjects are Protista, or animals, or plants, and it appears now as though *physiology* might eventually come to have as broad a connotation, as far as the phylogenetic relationships of our subjects for experiment are concerned, as *biology* has at the present time. Just as biology is the science that deals with all knowledge of living things, so *physiology* is the science that deals with all the *processes* or changes occurring in living things, with special reference to the conditions that control the rates at which these processes occur. Physiology is, then, the dynamic aspect of biology.

Conditional control. One other noteworthy clarification that has gradually found its way into physiological philosophy, largely during the last three decades, with the development of physical determinism in our science, has had to do with our general conception of causation and causal relations. Less than twenty-five years ago it was still taught in physiological laboratories that the relation of the rate of a given process (such as respiration, absorption, and so forth) to the intensity of any environmental or internal condition (such as temperature, concentration of solutions, and so forth) might be established by maintaining all other conditions constant and causing the intensity of the condition under investigation to vary from experiment to experiment. No attention was apparently to be given to the intensities of the other conditions; they were merely to be constant, or were to vary in the same manner for all comparable experiments. With more knowledge and with deeper thinking we have become aware that the constellation or complex of other conditions frequently exerts a pronounced influence upon the effect produced in the organism by a given difference in the intensity of the one condition studied. For example, if you wished to determine how concentrated must be a solution of copper sulphate in order to kill a wheat seedling, with its roots in solution and its leaves in air, you would naturally make the nutrient solution precisely the same in all of your cultures and you would add different amounts of the poison salt to the respective jars. Also, you would see to it that all jars were alike and that all cultures were subjected to the same temperature and light conditions, whether these were to be maintained constant or allowed to vary with time. From such a series of tests you would arrive at a fairly definite lethal concentration of the copper salt, and, until recently, you might have published this result with the idea that a generalization, at least for wheat seedlings of a given age, had been attained. But if you were to take another nutrient solution as foundation for all the cultures, if you were to shade them all or subject them all to another temperature or to a different series of temperature changes, thus repeating the series of experiments, otherwise as before, you would in all probability then establish quite another critical concentration of the poison salt. In short, how much of the poison is required to produce death depends quite clearly upon the other environmental conditions. Failure to realize this, failure to measure and describe all the other effective conditions—which were not thought of as being elements of the problem in hand—has frequently given rise to more or less serious polemics between different experimenters, and so to waste of time, energy and accumulated wealth.

From this conception of multi-conditional control has developed the well-known *law of the minimum* and of limiting conditions, which seems to have been useful in the interpretation of many physiological relations, but this principle is still quite incomplete logically, and its statement will assuredly become much more complex as our science advances. With a score or more of different kinds of conditions acting together to control the processes of our plants, and with an infinite number of possible combinations of the intensities of these various conditions, the problem of physiological control assumes almost a hopeless complexity. To illustrate, for a given plant, for a given total concentration of the series of Shive's[2] three-salt nutrient solutions and for a given set of climatic conditions, there is a certain set of salt proportions that gives the best growth. For another total concentration, however, all other conditions remaining as before, it is quite another set of salt proportions that are most favorable to growth. Adequately to work out the apparently simple problem thus suggested requires literally thousands of cultures.

I shall revert to this matter a little later, but I wish now simply to emphasize the point that we can no longer speak of a single condition as being the *cause* of an observed effect. The next generation of physiologists will have to learn to handle more than a single variable and to deal with *complexes* of conditions. They will not consider it a scientific statement to say that a certain concentration of poison, in the solution about the roots or in the air about the leaves, results in death, for they will realize that, with different nutrient solutions, with different rates of transpiration, and so forth, this concentration limit may have any magnitude within a wide range.

External and internal conditions. The idea of the conditional control of plant processes has resulted in the rather arbitrary, but very convenient, classification of the effective conditions in question, into two groups, *external* and *internal* conditions, and recent advance of plant physiology has had much to do with the measurement of the different members of these two groups and with the study of their relations. The morphological study of internal structures led to the consideration of the physiological processes by which these structures came into being, and it looked for a time as though a new branch of botanical science might thus arise. Goebel's later writings, on organography and experimental morphology, illustrate this movement. Since, however, experimental morphology is but the morphological aspect of the physiology of growth and development, it seems undesirable to create a new branch of science for this study, which appears recently to have become merged into certain aspects of ecology and physiology. Nevertheless, the relation of external and internal conditions to growth, as well as to other internal processes, is now occupying the time of many workers, and promises to be an important part of physiology in the future.

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[2] Shive, J. W., A three-salt nutrient solution for plants. Amer. Jour. Bot. **2**: 157–160. 1915. *Idem*, A study of physiological balance in nutrient media. Physiol. Res. **1**: 327–397. 1915.

This study of the sequence of internal conditions or states, as they follow one another in plants growing under natural conditions, now embraces all stages from the simply descriptive to the rather precisely quantitative. The more quantitative work along these lines also necessarily includes careful measurement of the controlling conditions.

Artificial and natural conditions. Along with this advance toward a causal interpretation of the natural processes of plants there has developed another aspect of the same kind of study, in which the older reverence for natural or "normal" phenomena has largely disappeared. Not very long ago that which was usual in nature as we knew it was called *normal* and we were led to think that a knowledge of what occurred in plants under so-called *abnormal* conditions was nearly useless or even undesirable. We have learned, however, that the range of conditions offered by nature does not generally happen to be great enough to allow adequate experimental interpretation of plant processes, and many kinds of artificial conditions have come to be employed in physiological experimentation. One of the great advantages of artificial experimental conditions lies in the fact that we know our conditions much better when we make them than we possibly can when we let nature furnish them to us.

The study of plants in the field requires quantitative knowledge of natural conditions, however, with all their great complexity, and methods for measuring these are being developed with considerable rapidity. This is the study that I have elsewhere termed *physiological ecology,*—physiological, because it regards the plant as a complex of processes controlled by physical and chemical conditions; ecology, because its aim is to interpret the phenomena of plant life in nature and with reference to natural conditions.

These two aspects of plant physiology must go on developing side by side. Ecology requires that natural plant phenomena be interpreted in an etiological way, and physiology itself requires that we should appreciate the fundamental principles of plant dynamics. A parallel may be found in the relation between mining and the chemistry of minerals, wherein very precise laboratory studies (with extremely artificial conditions) are just as important as the work of the prospector in the field.

For the further advance of physiology, better methods for producing controlled conditions are perhaps the greatest desideratum at the present time, and if a student has not a liking and a talent for creating physical and chemical conditions such as never have occurred in nature, he should not cast his lot with plant physiology, for the next generation.

Need of facilities for artificial control of conditions. I cannot forbear to dwell a moment longer on the need of controlled conditions in physiological work. Having laid aside the older idea that there is something everlastingly right in natural conditions and something almost akin to blasphemy in the employment of artificial ones, the physiologist comes to the same view-point as that held by the modern chemist or physicist, and he employs whatever conditions seem best for the enquiry in hand. Where would the chemist be if he were constrained to study his salts always as they occur in nature? If it is undesirable to study plants growing in quartz sand, is it not just as undesirable to study sugar solutions in distilled water or to use purified chemicals of any kind?

Now, if we wish to find out what chemical conditions are best suited to the development of plants it has long been our practice to control the chemical surroundings of our experimental cultures, and we have usually allowed the climatic conditions to fluctuate as they would. A very carefully selected plant may be placed in a very carefully washed Jena-glass jar of a very carefully prepared nutrient solution and the culture may be placed, forsooth, in a *north window* or in a *well-lighted greenhouse!* This anti-climax suggests the burden of my present plea. Our experimentation is of relatively little value, and we may know that it will soon be all to do over again, so long as we do not attend to the aerial environment of our experimental plants as thoroughly as we do to the nutrient media and the internal conditions as represented by pure strains, similar seeds, and so forth.

Obviously, what is needed is properly equipped laboratories, where climates may be made to order as truly as soil solutions are now commonly made. Such laboratories cannot be arranged with slight expenditure in rooms of an architect's building; they must be planned from the ground up, or rather, from the ground down, for I suspect they will be underground, for easy climatic control. A greenhouse used to be what the experimental physiologist first asked for, in the future he will demand elaborately equipped chambers, thoroughly protected from the influence of natural conditions. The physical sciences have now placed in our hands all the equipment for such culture chambers, and what we have to do is simply to adapt and arrange such equipment. For more than a decade I have watched the improvement in electrical devices for producing light, with the idea that these were the only instruments not already suited to our purposes. Very recently the production of nitrogen-filled incandescent lamps has practically filled this gap. The enclosed mercury arc has been available for a longer time and has actually been employed in physiological studies. Temperature and humidity control are now fairly simple; the arrangements for these, as needed in our experimentation, are already in use in many manufacturing establishments.

The initial expense connected with the sort of laboratory of which I am dreaming will retard the making available of these much needed facilities, but a tardy recognition of the value of plant processes to mankind should eventually place at the disposal of plant physiology at least as elaborate apparatus as is now employed by modern astronomy. Almost as little of really lasting value (in connection with higher plants, at any rate) may be expected of a physiologist in his present laboratory as might be expected of an astronomer compelled to work in an attic room with a dormer window!

Internal conditions. Internal conditions, within the plant, have received much attention, from the beginning of physiological studies, and the last quarter-century has seen a rapidly increasing interest in these, mainly from the physico-chemical point of view. The whole science of biochemistry, and even its very name, have developed practically within the period since this University was founded. A general physical chemistry of cells, which was new to physiology in the 90's, has broadened and deepened to form a much more special chemistry and physics of physiological solutions, and now the new field of colloid chemistry is rapidly being opened for physiological study. Such words as *enzyme*, *semi-permeable membrane*, *protoplasm*, as these were first used, are becoming unsatisfactory, as the things that they connote are better understood. These generally descriptive words will be retained, but their meanings to the physiologist of today are vastly different from their meanings to similar students of twenty-five years ago, and future students will read into them much that we do not now suspect.

The whole subject of cell membranes, as these influence diffusion rates and turgor, is undergoing a thorough overhauling. I may mention, for example, that the cell wall was regarded as almost always readily permeable to all plant solutes, at the end of the last century; and now we may not discuss semi-permeability of plant membranes without considering these walls. Some of the recent studies upon the permeability of cell walls, as you know, have been carried out in the plant physiological laboratory of this University.

If many of the impressive terms of a few decades ago seem to have lost their charm, we still have charmed words, with which to conjure. *Hormones*, *anti-bodies*, the *determiners* of the geneticists, are examples of these. As our own Professor Barnes used to say, such words are "cloaks for our ignorance," and they may be expected to lose *their* charm at a still later day, when our ignorance, in these connections, having become somewhat clothed with knowledge, may no longer require a cloak.

Relation of plant ecology, agriculture and forestry to plant physiology. In closing, I should like still further to emphasize the intimate relation between plant physiology and ecology. I regard the province of the last-named branch of science as the interpretation, in terms of controlling conditions, of all plant phenomena as they occur in nature. Ecology must, then, include all that is science in agriculture and forestry, for these sciences deal mainly with natural conditions. It is of little importance whether seed was sown by wind, by the movements of birds, or by those of man; it is also of little importance whether the plants growing from this seed are probably destined to be devoured by human beings or by insects and fungi; the fundamental problems of agriculture and forestry are the same as those of what is commonly called ecology. Ecology may be considered as applied physiology and the arts of agriculture and forestry are largely applied ecology.

For a long time botany, in this country at least, held itself aloof from agriculture and contented itself with "teaching teachers to teach teachers to teach." The plant physiologists of the university laboratories had little sympathy with the application of their science, and agriculture and forestry were compelled, perforce, to establish their own schools, where the kind of botany they needed might be taught. When ecology arose, only a few years before the founding of this University, it too was almost scorned by many professional botanists. In spite of much disapproval ecology has grown, however, in these last three decades, to be a wondrously strong and healthy child of the *scientia amabilis*, so that ecological papers now occupy a rather large portion of the programs of our botanical meetings. This vigorous child has introduced into the house of botany a sympathy for the problems of agriculture and forestry that was not prominent before, for it has not held itself so completely aloof from agriculture and forestry, there having been a close relation between ecology and these almost from the very start.

Plant physiology has felt the ecological movement very strongly, and many workers in this subject have turned a good portion of their attention to field interpretations. With this awakening our science has come into close connection with agriculture and forestry, and it seems unlikely that this connection will ever be seriously weakened. Our university laboratories of plant physiology still teach teachers to teach, but the hopeless cycle is frequently broken when some of the teachers that have been taught do not teach, but enter into investigation, in experiment stations and other research institutions.

The arts of plant production have shown us problems that were worth our serious attention, both scientifically and financially, and they have furnished the facilities for the solution of these problems. I am sure they will continue to do this more and more, as time goes on, so that the future of plant physiology promises to be as closely linked with the practical questions of agriculture and forestry as is the present of animal physiology with the practical questions of medicine, surgery and hygiene. As rapidly as those who are deeply familiar with plant physiology become able to see the possible applications of their science, new fields will be opened, which will mean much to human welfare as well as to the pure science itself.

Not only do governmental and endowed research institutions, interested in agriculture and forestry, offer facilities, opportunities and money for the prosecution of physiological research on plants, but private corporations and farmers' associations are also entering this field. Perhaps the best example I can give of what pure science can do for the art of plant production, is found in the work of one of our own number, of the doctors of this Department of Botany, who has actually created, out of a wild species, an exceedingly valuable cultivated crop hitherto unknown in the world. While doing this he has been in the employ of a commercial corporation.

There seems to be no doubt that the future of plant physiology and plant ecology lies with agriculture and forestry. It is these arts that are to supply the elaborate equipment needed for truly scientific studies of the relations between controlling conditions and plant processes. Just as theoretical physics draws upon engineering for its financial support, so must theoretical plant physiology depend upon the arts of plant production. Thus, through its youngest branches, physiology and ecology, the *scientia amabilis* is becoming also a *scientia utilis*, but with this great change it will still remain as truly a *scientia* and as truly *amabilis* as it has ever been in the past.

NOTES ON THE HISTORY OF THE WILLOWS AND POPLARS

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The name willow suggests to most dwellers in temperate climes the graceful pendulous branches of the weeping or so-called babylonian willow or the silky catkins of the pussy-willows collected in the early springs of our childhood days. We associate the gnarled trunks of willows with Carot's paintings, or, if we have chanced to live in certain districts, we think of the willow chiefly as a cultivated crop the shoots of which are utilized for the making of baskets, wicker furniture and willow-ware. Possibly in youthful chemical experiences we have tried to make gun-powder from willow charcoal, or charcoal crayons, and what American boy does not know that willow wood makes good baseball bats or that whistles can be manufactured from the twigs. Willow, of course, enters into a great variety of uses, some of which will be enumerated, but probably its oldest use was the plaiting of its shoots into baskets or similar articles. I have no doubt, that the men, or more likely the women, of the old stone age made baskets of willow twigs, since plaiting is part of the culture of the most primitive of existing peoples. Basket willows were cultivated by the Romans, who used the shoots for making bee hives, baskets, garden and vineyard trellises. The light elastic wood they covered with rawhide and bossed with brass for the shields of their legionaries. Pliny mentions four species of willow so used in his day (*Salix fragilis*, *S. purpurea*, *S. amygdalina*, and *S. viminalis*).

During the Middle Ages the basketmakers guilds were of considerable importance particularly in France, Germany and the Low Countries. These sank into insignificance during the seventeenth and eighteenth centuries when they were replaced by itinerant basket makers, who were sufficient for supplying the local demand. With the advent of the factory system and the simultaneous great increase in trade and communications, the demand for baskets and hampers for parcel shipments of all kinds gave a great impetus to basket making, particularly in Europe where labor was so much cheaper than in America. This, coupled with the constantly increasing popularity of wicker furniture, has resulted in a constant and increasing demand for willow shoots. Napoleon's embargo stimulated willow culture in Britain, and considerable areas in our eastern states have long been devoted to this purpose, usually however with little selection as to species cultivated or cultural methods.

The willows and poplars, which constitute a separate family and order of plants, are characterized by a number of well marked morphological features. They have soft light wood, astringent bark, watery sap, scaly buds and deciduous leaves—short stalked in the willows, long stalked in the poplars—arranged alternately and with stipules. The flowers are in the form of catkins which bloom in the early spring in advance of the unfolding of the leaves. These catkins are generally upright in the willows and pendulous in the poplars, and the male and female are borne on different plants. The seeds, which are tufted with silky or cottony hairs, are formed in one celled, two to four valved capsules, and are dispersed by the winds.

By reason of their rapidity of growth, tolerance of moisture (the name *Salix* is said to be derived from the Celtic *sal* = near and *lis* = water) and their great adaptability to all kinds of soils they occur in a variety of situations and the different members of the family are found from the north polar region to the equator and beyond. They are gregarious because of the ease with which they grow from suckers and sprouts, their great vitality and free formation of shoots and seeds. About the only inimical condition that proves fatal is shade, of which they are very intolerant, hence in the natural growth of the forest they tend to become replaced by slower growing trees which eventually overtop them. Thus in time they become restricted (especially the willows) to river bars, mud banks, peat bogs, mountain tops and similar unfavorable situations. Both willows and poplars are very fast growers and both are relatively short lived. The majority are not tall trees and the seeds quickly lose their vitality and the trees are much damaged by winds because of their brittle wood.

The willows are far more diversified and more widely distributed than the poplars, and the facility with which hybrids are formed and the trivial specific differentiation of so many of the species makes them a very baffling group for the systematic botanist. Although both willows and poplars come from a very old stock, a stock as old as any of our trees except the conifers, and one much more ancient than that of our familiar warm blooded animals, the willows seem to have reached the zenith of their development in post glacial times, while the poplars on the other hand were more varied and widespread in earlier geologic times.

There are about 200 existing species of willows of all grades of stature, and while we think of them as especially characteristic of the North Temperate Zone they are by no means confined to it but range from the Arctic Circle southward across the equatorial regions into the South Temperate Zone. In America there are upwards of 100 species, ranging in size from tiny plants a few inches high under the Arctic Circle to trees 140 feet tall and 4 feet in diameter in more genial situations, as in the bottom lands of the lower Mississippi. About a score of these are trees. They are found from tidewater to the snowline of mountains and from the Arctic through Canada and the United States to the Gulf, and from the Atlantic to the Pacific. They occur in the West Indies and Central America and southward to the Chilean Andes. In the Old World they range from Arctic Europe and Asia southward over both of these continents to Madagascar and South Africa, and from the Himalayan region southeastward through Malaysia to Java.

Aside from the older uses of willow as cover to prevent erosion or for basketry or charcoal, its utilization for lumbering has had a relatively modern development. At the present time low grades are largely used for box and cooperage material while the higher grades are employed for furniture drawers and backing, as well as for refrigerators, cabinet work and cheap furniture. Willow planking is satisfactory for purposes where strength is not required, since it does not warp, splinter or check, and this property determines its use for boat parts such as keels, paddles, etc., and for athletic goods, cutting boards, toys, etc. Large quantities are also consumed every year by excelsior mills.

The oldest known willows, not certainly identified, are recorded, along with the early representatives of other dicotyledonous plants, from the Lower Cretaceous of Portugal. During the earlier part of the Upper Cretaceous, the time when the remains of the higher or socalled flowering plants first become prominent in the geological record, a great many species of undoubted willows have been found. Upwards of a score of forms have been described and the ancestral stock during these early days must have possessed some of the vitality that marks the recent forms for it spread rapidly over North America as well as Europe and probably over Asia as well, although there are no known records from the last continent. It should be noted that four-fifths of the known Cretaceous species are North American and that none have been found in the prolific Cretaceous plant beds of Greenland, although poplars were abundant at that time in the far north.

Botanists are divided in their interpretation of the willow flower, some regarding its simplicity as a primitive character and others regarding it as reduced by evolution from more evolved types. Whichever view is correct the willows undoubtedly appear early in the geological record and there is absolutely no basis for regarding the terminal wood parenchyma as supporting the reduction theory, as is done by Holden.[1]

The oldest Tertiary, or Eocene, deposits have furnished about 25 species of willows, the records including all of the continents of the Northern Hemisphere. Willows had now reached Greenland, where five different species have been discovered. Other

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[1] Holden, R., Ann. Bot. 26: 171. 1912.

Arctic lands also shared this invasion, since willows have been found in beds of this age in Alaska, at the mouth of the Mackenzie River, in Iceland and Spitzbergen. The climate of the earth seems to have been warmer during Eocene times since we find many tropical plants in the Mississippi valley and as far north as southern England, and the Arctic lands at this time were clothed with dense forests of a temperate type.

The Oligocene, which succeeds the Eocene in the Tertiary sequence, was a time of prevailingly marine deposition in North America so that few fossil plants are known and there is only one willow among them, although doubtless willows still flourished since they are common in succeeding deposits. In Europe about half a dozen species are known from the Oligocene rocks.

The next period—the Miocene—was a time of great variety and luxuriance of tree growth. Between forty and fifty different willows are known and the actual number in existence must have been much greater for when we get a glimpse into the past in an otherwise unknown area, like that furnished by the tiny lake basin at Florissant in the Colorado Rockies we find an abundance of willows—five have been described from Florissant. They are equally abundant in the lake beds and elsewhere throughout Europe. A few are known from eastern Asia and in America they occur in Virginia on the East coast and in Oregon and California on the Pacific coast.

The Miocene was succeeded by the Pliocene period, a time during which the forests of the Miocene continued practically unchanged. Many willows whose characters foreshadow their existing descendants are known from Asia Minor to Spain, but unfortunately for our history the American Pliocene deposits are for the most part marine marls so that the American Pliocene plant record is a blank, although we know that the familiar types must have been present since willows are abundant in the next or Pleistocene period.

The Pleistocene, or period of continental glaciers, was an epic time for all plants and animals, for it was a time during which ice sheets many feet in thickness gradually accumulated in northern America and Europe and in the more elevated mountains. After fluctuating near a maximum for some thousands of years these ice sheets gradually disappeared and were followed by a long genial interglacial stage. This great accumulation and southward advance of the ice was repeated four times and the last ice sheet has been gone only a few thousand years. During these changing times all life forms were subjected to new competitions and great stresses, hence many forms succumbed. Others shifted back and forth with the shifting climatic conditions and still survive. A great many still existing species of willows, as well as other trees, make their appearance in the Pleistocene bogs, lake beds and river terrace deposits and thus serve to record the gamut of changing environments. We find for example the tiny Arctic willows like *Salix polaris,* which today occurs in the Scandinavian mountains and reaches its southern limits in the tundras along the Arctic coast of Russia, present in the Transylvanian and Swiss Alps, throughout Britain, southern Sweden, Denmark and the north German plain, associated with other plants of the far north such as *Dryas* and animals like the Arctic fox and lemming.

The accompanying sketch map of Europe shows the unusual climatic conditions which enabled this far northern form, now confined to the lined area on the map, to extend southward almost to the Mediterranean. This and other herbaceous or shrubby species of Arctic willows are found at innumerable localities throughout central and northern Europe, where the deposits of this age have been so intensively studied. The conditions were duplicated in North America but as we have devoted so little study to the life of our Pleistocene deposits it is not possible to obtain adequate records of the distribution of our Pleistocene plants.

Over twenty kinds of willows have been discovered in the Pleistocene deposits and only two or three of these are extinct species. The details of their present range and Pleistocene occurrences are too extensive for the present sketch so that only a few will be mentioned. One or the other of the four herbaceous small leafed arctic and alpine species—*Salix herbacea, S. polaris, S. retusa* and *S. reticulata* are found in Pleistocene deposits as far south as New York state in this country, and Switzerland and Galicia in Europe. Three of them occur in Germany. The northern peat bog species *Salix repens* and *S. myrtilloides* are both found in England. The sub-arctic species *Salix aurita* and *S. caprea* occur respectively in England and Denmark. The osier or basket willow is recorded from France and Württemberg, and a very similar form occurs in the Pleistocene deposits of North Carolina and Kentucky. The white

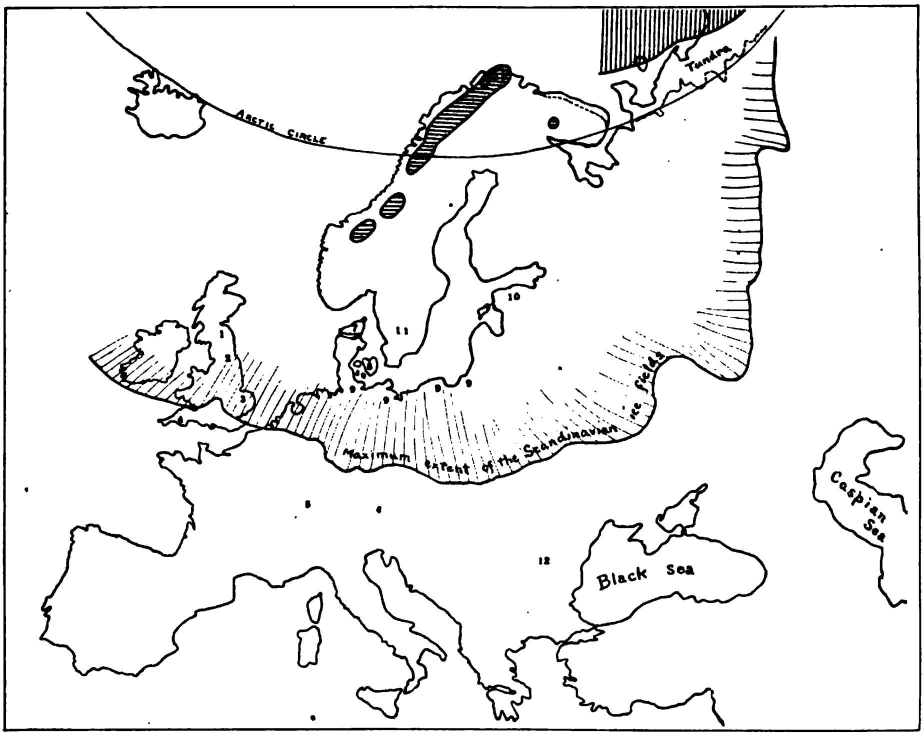

Fig. 1. Sketch map of Europe showing the limits of the continental ice sheet, the present distribution and the Pleistocene occurrences of *Salix polaris* (modified from Nathorst, 1891). *1*, vicinity of Edinburgh; *2*, localities in Yorkshire; *3*, localities in Norfolk and Suffolk; *4*, Devonshire; *5*, numerous localities in the Alps; *6*, localities in Bavaria; *7*, localities in Jütland; *8*, localities in Zeeland; *9*, numerous localities in North Germany; *10*, localities in Esthonia, Livonia and Vitebsk; *11*, numerous localities in Schonen, Gotland and Jemtland; *12*, Felek in Hungary.

willow (*Salix alba*) and the crack willow (*Salix fragilis*) both occur in France and Württemberg. With the amelioration of conditions following the last retreat of the ice the Arctic forms withdrew to the far north with the sub-arctic and cool temperate species in their wake, and these far northern forms are circumpolar at the present time, although those willows that attain to the stature of trees and inhabit the Temperate Zone are different in each of the three continents of the Northern Hemisphere.

The poplars, while they show their community of origin with the willows, differ from them sufficiently to be readily distinguishable. They are all trees and on the whole average larger than the willows. The catkins are pendulous instead of erect; there is a rudimentary perianth or flower envelope, and the bracts of the flowers are toothed or cleft instead of entire as in the willows; the leaves are usually broad instead of narrow being ovate or deltoid and often cordate, and the leaf-stalks are long and often flattened—a feature well exemplified in the quaking aspen.

The generic name *Populus* is of obscure etymology but was the classical name of the poplar, of which there are several European species. The most important of these is the white, silver poplar or abele (*Populus alba*), a large tree of the central and southern parts of that continent. The black poplar is also a large tree of central and southern Europe and Asia. An aspen (*Populus tremula*) occurs in central and northern Europe ranging eastward to Japan, and there are a number of additional European species, including the downy poplar (*Populus canescens*); *Populus monilifera,* which furnished the poplar wood of the Romans; and the so-called Lombardy poplar (*Populus fastigiata*) so often planted in this country as a screen or ornamental tree. The last is probably of oriental origin despite its name, coming originally from the region of the Vale of Kashmir, since it seems to have been unknown in Italy in Pliny's time. *Populus euphratica* of North Africa, the Altai and Himalayan region is believed to have been the weeping willow of the Scriptures and its wood along with that of the date palm furnished the rafters for the buildings of Nineveh. The bud gum of the European black poplar and of our American balsam poplar has often been employed by herbalists for various medicinal purposes although it has little virtue.

There are in all about twenty-five existing species of poplar, of which half are found in North America. Among these the ones known as aspens have an especially wide range, particularly the quaking aspen, *Populus tremuloides,* which covers 112 degrees of longitude and 41 degrees of latitude, while the European aspen (*Populus tremula*) covers 140 degrees of longitude and 35 degrees of latitude—the two together nearly encircling the globe. They form dense growths in the north woods and furnish most of the drift wood of the Arctic Ocean. Although cut in vast quantities for pulpwood the aspens will probably always form an important element in the more northern forests as they and their ancestors have done during the past three or four million years. They repeat the usual poplar characters of smooth bark, soft weak wood, very rapid growth and sparse broad leafed foliage. They are more gregarious and somewhat smaller at maturity than the other poplars and their long slender leaf stalks cause the lightest summer breeze to set the leaves to quaking or trembling with the characteristic motion and sound that gives them their vernacular names. Other interesting poplars are the so-called cottonwoods of the West, where they are almost the only native trees in the river valleys of the prairie country, ranging from Assiniboia to New Mexico. The cottonwood has narrower leaves than the rest of the poplars which in the commonest species approaches a willow leaf in appearance.

Neither willow nor poplar timber can compete with larger and stronger woods such as pine or spruce or with more durable woods such as oak, cedar, and chestnut. Pulpwood, excelsior, and fuel are their largest uses although for barn floors, boxboard veneer, spools, matches, etc., their qualities of softness, lightness, ease of working and lack of splintering, render them valuable.

The geological history of the poplars is most interesting, there being about 125 fossil species, in addition to the still existing species that are found fossil in the Pleistocene deposits. The oldest known were the contemporaries of the dinosaurs of the closing days of the Lower Cretaceous. One small leafed form is found at this early day in the Potomac River valley and the other, which was for a long time the oldest known dicotyledon, comes from the Kome beds of western Greenland and was named *Populus primaeva* by Heer, its describer.

These first poplars are rare forms but their geographical separation gives us a hint that their abundance was greater in those early days than the records show, and this is also indicated by the abundance and wide distribution of poplars during the Upper Cretaceous, from which about thirty species have been described. They are much less abundant than the willows in the Upper Cretaceous of Europe but, unlike the willows, they are common in Greenland, and they are exceedingly ubiquitous in North America at this time, especially in the West where they appear to have been very common along the borders of the Upper Cretaceous sea that submerged so much of the then low western country. In addition to the American, European and Arctic records a petrified piece of a poplar root has been described from the Upper Cretaceous of Japan, indicating that Asia had its species then as now.

During the succeeding Eocene period there were upwards of 50 species, or twice as many as are living at the present time. The rising land of what is now the Rocky Mountain country shut off the moisture laden winds from the Pacific and the lessening rainfall made of this vast region a quite different country from what it had been during the Upper Cretaceous. In the continental deposits of the Eocene, that is deposits laid down on the bosom of the land rather than in the sea—the deposits of wind blown materials and volcanic dust, laid down in lakes, streams, floodplains, etc—deposits referred to the Fort Union formation, leaves of poplars are the most abundant fossils.

Poplars appear to have covered at this time all of the plains and mountain country of the West in great variety, extending northward from the western provinces of the United States and

Canada to Alaska and the mouth of the Mackenzie River, and encircling the globe in high latitudes. They have been recorded from Greenland, Grinnell Land, Spitzbergen, Sachalin, Siberia and Manchuria. A few are found in central Europe, but the great bulk are American and Arctic, and the climate of more southern lands appears to have been too warm for their presence in any great numbers, for in the abundant Eocene floras of southeastern North America we find no traces of poplars but in their place a subtropical flora of figs, laurels, bread fruit, rain trees and their allies, thatch and date palms, nutmegs, pond applies, and similar types unfamiliar to dwellers in the Temperate zone. This subtropical flora extends as far north as the mouth of the Ohio in America and a similar warm flora extends to southern England in Europe.

During the Oligocene, which succeeded the Eocene, the scanty records have yielded few poplars. Three species have been described from deposits of this age in the West and four or five are known from central and southern Europe. Southeastern North America was still too tropical in its climate to permit the existence of poplars and although we lack the proof it may be assumed that the numerous Eocene forms lived on in Arctic lands until they were gradually exterminated or driven southward by the more severe climate that commenced to prevail in high latitudes before the close of the Oligocene.

The poplars are represented during the Miocene period by about thirty species, which are found from Greece westward to Spain in Europe and throughout the western United States and Canada. The Miocene lake of Florissant in the heart of the Colorado Rockies has furnished seven forms of poplar—one a splendidly preserved cottonwood that may well have been the ancestor of the existing forms that are found at the present time in Colorado. Poplars are found at this time along the Pacific Coast, but none are known from the Atlantic or Gulf Coasts.

The Pliocene period, which succeeded the Miocene and immediately preceded the Glacial period, has furnished about 16 species of poplars, several of which are very close to, if not identical with, still existing European forms such as the European aspen, the silver poplar and its downy leafed ally. They are found during this period from Asia Minor to Spain, but there are no known American records, since this country has unfortunately yielded scarcely any Pliocene plants.

The Pleistocene or Glacial period is always of particular interest to students of plant history and distribution since the presence of continental ice sheets and the complex physical conditions which their presence brought about played havoc with the uniformity of development and distribution of the noble races of both animals and plants that had been flourishing for so many thousands of years throughout the Northern Hemisphere.

Poplars are represented in the Pleistocene deposits of Europe and America by wood, leaves, bud-scales and catkins. Only two of the ten species recorded from these deposits are extinct and these are both from the earlier Pleistocene of Maryland and are very similar to existing forms. In Europe the black poplar is recorded from Italy; the downy white poplar has been found in both England and France; and the European quaking aspen occurs in peat deposits at a number of localities in Denmark, Germany, northern Italy, etc. In America the so-called necklace poplar (*Populus deltoides*) has been found in river terrace deposits in Alabama and western Kentucky, and the balsam poplar or Tacamahac, and the large toothed aspen, have been found in the Interglacial beds of the Don valley in Ontario and the former has also been found in the blue clays of Maine.

Thus we see that while the life span of both willows and poplars is much shorter than that of most of our forest trees, the stock is a virile one and the race an ancient one. While neither have been objects of veneration or worship like the oaks or ginkgoes, or of surpassing utility like so many of our forest trees, both were the associates of our remote ancestors of the Old Stone Age when the last ice sheets were retreating from northern Europe and the Nordic race was being evolved. Both willows and poplars must have been familiar and useful plants to the Neolithic men that evolved the so-called Robenhausian culture of the Swiss lake dwellers (7000–5000 B.C.), the remains of whose dwellings, built on piles and found so abundantly throughout the region of the Alps and the valley of the Danube, record the time when early man ceased being merely a nomadic hunter and came to occupy fixed abodes and garnered some crops. And when the race passed from lake dwellings to fortified and moated habitations in the swamps and along the rivers of southern Europe, the willows must have been one of the familiar and useful plants in their immediate environment, during what is called the Terramara period, so that they should have at least a sentimental interest for the modern race.

BOOKS AND CURRENT LITERATURE

Absorption of Carbohydrates by Green Plants.—The fact that phanerogams are capable of absorbing by means of their roots a considerable number of organic substances and assimilating them, is not a matter of general knowledge among botanists. A recent memoir by Knudson[1] brings together the earlier evidence in support of this fact and contributes in addition, a considerable body of data in substantiation of it. Special emphasis is given to certain phases of the problem, namely, the comparative ease of assimilability of the several sugars employed and the influence of varying concentration on growth and respiration. Several species of plants including corn, Canada field pea, radish, cabbage, vetch, wheat, timothy, and sweet clover were employed. The seed were germinated and grown for a period of thirty days in tubes containing agar to which a nutrient solution and either glucose, fructose, maltose, or lactose were added. The dry weight of roots and tops was used in the determination of the amount of growth.

It was found that not all of the species were able to utilize the same sugar equally well. It was further noted that a certain sugar gave the best growth when the plant was kept in the light while a different sugar exerted the most beneficial effect in the darkness.

Respiration was manifestly influenced as early as the fifth day of the experiment.

Concentrations of galactose as low as 0.0125% were injurious to vetch, Canada field pea, corn and wheat. This toxicity could be antidoted because of an antagonistic action which was found to exist between galactose and glucose when certain concentrations were employed.—Frederick A. Wolf.

Root Hairs.—Roberts, in a recent contribution from the Hull Botanical Laboratory,[2] reports some results obtained in her study of root hairs. She finds that the ratio between the length of cortical and epidermal cells does not determine root hair production. Corn roots were used, and measurements of both smooth and haired epidermal cells were compared with those of adjacent cortical cells. The initial swelling which results in a root hair protuberance is not due to the position of the nucleus, but to the less resistant nature of part of the outer wall as compared with the remainder of this wall, and to the excess of internal pressure of the cell over the opposing pressure on the external wall. The internal pressure was found by measurement with sucrose solution to exceed the external pressure by about four atmospheres. Reduced moisture content of the surrounding air decreased the extensibility of the wall thus retarding root hair development. Investigation of the structure and composition of the walls of various root hairs (alfalfa, amaranthus, barley, corn, cabbage, daucus, morning-glory, pea, tobacco, tradescantia, and others) showed in every case excepting corn an outer layer of calcium pectate and an inner one of cellulose. Some of the root hairs investigated had in addition to the two layers a callose layer at the tip. Corn root hairs had only a cellulose layer. The pectin layer is closely related to the absorption and retention of water by the hair, and the cellulose layer strengthens the wall. The formation of cellulose mucilage in corn, and of pectin mucilage in the other root hairs investigated, makes possible the close relation that exists between root hair and soil particles.—J. G. Brown.

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[1] Knudson, Lewis, Influence of certain carbohydrates on green plants. Cornell Agr. Exp. Sta. Mem. 9, 9–75, fig. 11. 1916.

[2] Roberts, Edith Adelaide, The epidermal cells of roots. Bot. Gaz. 62, 488–506. 1916.

Tropical Agriculture.—Our increasing interest in tropical countries and their development will give a useful place to Wilcox's recent book on the agriculture of the tropics.[1] A large and well selected series of tropical crops is described with an amount of detail depending upon the commercial importance of each of them. Sugar, rubber, sisal, coffee, the banana, and the coconut, for example, are given an extended treatment covering the botanical description of the plants which yield these products, their propagation, cultivation, harvesting, yield, and preparation for use.

The book is sufficiently elementary to enlighten those who still believe that bananas hang from the tree as they hang in the fruit shop, and it is so full of well arranged material that it is sure to contain a great deal of fresh information for every reader in the temperate zone. No partiality has been shown to any portion of the tropics in the selection of a relatively small number of crops and plants from the enormous number involved in the agriculture of the tropics as a whole. The fact that the same plant is often grown in widely separated regions means that the selection of universal popular names is impossible. Persons with experience confined to the western hemisphere will not recognize in "kapok" the tree known as "ceiba" in Spanish-America and as "silk-cotton" in the British West Indies. Other plants with a rich synonomy, such as the dasheen, or taro, are given their entire complement of names.

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[1] **Wilcox, E. V., Tropical Agriculture, pp. 373, pls. 33. New York, D. Appleton and Company, 1916. ($2.50.)**

Inasmuch as the volume is designed to give information to the prospective settler or investor, there is considerable importance in the chapters on tropical climate and soils, on the general methods of tropical agriculture and on the economic and social conditions of tropical lands. It is of interest to find the fact getting into print that the tropical climate is not insidiously harmful to the white man if he will take active physical exercise, just as if he were still in the so-called temperate region.—FORREST SHREVE.

NOTES AND COMMENT

About four hundred degrees in botanical science, including some titles in bacteriology and general physiology, have been conferred by American universities during the last decade. This number is about equivalent to the present active membership of the Botanical Society of America, although it is by no means to be taken for granted that all of the doctors are members in that organization. A file of the theses would constitute a special history of research during the period in question. Great difficulty would be encountered in making a collection of these papers, as some have not been published in their entirety or under the thesis caption, others have been privately printed, and some still repose in manuscript form on the shelves in the library of the institutions which acknowledged their seriousness and value by granting a degree.

The galleys of an article discussing the doctorates in all subjects in American universities in 1916 have been received from Prof. J. McKeen Cattell. An examination of this list shows that about 37 are of such character as to be reviewed in botanical journals as compared with 45 in the previous year. About one-half of the subjects are descriptive of work done in physiological laboratories. One is in genetics, one in cytology, one in soil physics, two are in bacteriology, and the remainder may be apportioned equally among morphology, taxonomy, pathology, and ecology. Many of the papers deal with problems of importance, and appear to deal with the results in a broad way. The character of the list indicates that serious work is expected of the candidate. It is hoped that this attitude also implies a disposition to annoy the earnest student with fewer formal requirements and superfluous irrelevant minor courses.

COLUMBIA UNIVERSITY

Edgar Altenburg. Linkage in *Primula sinensis*.
Clifford Harrison Farr. Cytokinesis of the pollen-mother-cells of certain dicotyledons.

CHICAGO UNIVERSITY

Sarah Lucinda Doubt. Response of plants to illuminating gas.
George Konrad Karl Link. A physiological study of *Fusarium* in relation to potato disease.
Edith Adelaide Roberts. The epidermal cells of roots.
Rachel Emilie Hoffstadt. The vascular anatomy of *Piper methysticum.*
Millard S. Markle. The root systems of certain desert plants.
Mabel Lewis Roe. The development of the conceptacle in *Fucus.*
Charles Albert Shull. Measurement of the surface forces of soils.
Arthur Gibson Vestal. The phytogeography of the eastern mountain-front in Colorado.
Frank Earl Denny. Permeability of certain plant membranes to water.
Alphaeus William Dupler. The gametophytes of *Taxus Canadensis* Marsh.
Leslie Alva Kenoyer. Environmental influences of nectar secretion.

HARVARD UNIVERSITY

Sumner Cushing Brooks. Studies on the permeability of plant protoplasm.
George Gaulterus Stevens. The flora of Oklahoma.

THE JOHNS HOPKINS UNIVERSITY

Arthur Gillett McCall. The physiological balance of nutrient solutions for plants in sand cultures.

UNIVERSITY OF PENNSYLVANIA

Arabel Wilson Clark. Seasonal variation in water content and transpiration of leaves of beech, witch hazel and white oak.

CORNELL UNIVERSITY

William Carlyle Etheridge. A classification of the cultivated varieties of oats.
Arthur Jackson Mix. Studies on the sun scald of fruit trees.
Otis Freeman Curtis. The stimulation of root growth with special reference to the formation of roots in cuttings.
Louis Melville Massey. The hard rot disease of Gladioli.

James LeRoy Weimer. Three cedar rust fungi; their life histories and the diseases they produce.

UNIVERSITY OF WISCONSIN

Williams Nicholas Steil. Apogamy in *Nephrodium hirtipes* Hk.

Orville Turner Wilson. A study of *Pseudopeziza medicoguis* (leaf spot of alfalfa).

Vive Hall Young. Some factors affecting enzyme formation in certain fungi.

UNIVERSITY OF ILLINOIS

Fred Wilbur Tanner. A study of green fluorescent bacteria from water.

John Asbury Elliott. Taxonomic characters of the general *Alternaria* and *Mascrosporium.*

Ernest Michael Rudolph Lamkey. Absorption and transpiration as affected by temperature and humidity.

Rosalie Mary Parr. The response of *Pilobolus* to light.

Harry Dwight Waggoner. The viability of seeds as affected by high temperatures and water content.

UNIVERSITY OF MICHIGAN

Reed Oshea Brigham. Assimilation of organic nitrogen by higher plants and its modification by the action of *Bacillus subtilis.*

UNIVERSITY OF CALIFORNIA

Arthur Hugo Ayres. The influence of the composition and concentration of the nutrient solution on plants grown in sand cultures.

Robert Percy Brandt. Notes on the Californian species of *Trillium* L. Seasonal changes in *Trillium* species with reference to the reproductive tissues.

Robert Humphrey Forbes. Certain effects upon crop plants of copper in irrigating waters.

Pierre Auguste Boncquet. *Bacillus Morulans,* n. sp., a bacterial organism which inhabits the sieve tubes of sugar beets and related plants; its characters and significance.

UNIVERSITY OF MINNESOTA

John Ernst Weaver. A study of the vegetation of southeastern Washington and adjacent Idaho.

UNIVERSITY OF MISSOURI

John Herman Winkler. An investigation of the relation between vegetation and reproductive activity in plants.

—D. T. MacDougal.

The sandalwoods of Hawaii form the subject matter of a bulletin of the Hawaiian Board of Agriculture and Forestry, prepared by Mr. Joseph F. Rock. Nine species and two varieties of *Santalum* are indigenous to the islands, where they appear to have formerly composed a very important part of the dry lowland forests. It is stated that all of the Hawaiian species are parasitic upon the roots of other trees, although they are not obligate parasites. The principal source of sandalwood has been the forests of *Santalum album* in southern India, but a number of other species, as well as some members of other genera and families have been of commercial importance. This famous wood, the mention of which is so familiar in all south sea tales, is still in demand for cabinet work in tropical countries, because of its immunity from the attacks of termites, it is used as a source of dyes and oil, the wood is largely used in the orient for carving, because of its odor, and it is burned by the Chinese as incense.

The report of the Chief of the Division of Publications of the Department of Agriculture states that a total of 39,098,239 bulletins, pamphlets, circulars, and reports were issued by the Department during the last fiscal year. Nearly one-fourth of this number consisted of reprints of earlier publications, while about one-third of the total was made up of Farmers' Bulletins.

A recent fascicle of the first volume of the Puget Sound Marine Station Publications contains eleven papers based on work done at the station at Friday Harbor. These are all devoted to the morphology, distribution, or physiology of the algae of the northwestern coast.

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OBSERVATIONS ON A NEW TYPE OF ARTIFICIAL OSMOTIC CELL

JOSHUA ROSETT

Baltimore, Maryland

INTRODUCTION

Students in plant physiology are familiar with what is called Traube's[1] artificial cell—one of the means by which osmotic pressure and some of the properties of precipitation membranes are frequently demonstrated to elementary classes. It will be remembered that these cells are formed by placing a fragment of $CuSO_4$ in a weak solution of $K_4Fe(CN)_6$, that a brown membrane of copper ferrocyanide is instantly formed about the mass, and that the cell thus formed enlarges for a considerable time, this enlargement being due to repeated osmotic ruptures of the membrane and subsequent closings of these openings by new precipitation.

The writer has been interested in the osmotic and chemical phenomena involved in this sort of "osmotic growth," and has been able to improve the technique so as to bring out several new details of the processes involved. Some of the results should be of interest to physiologists as furnishing examples of certain physico-chemical and colloid-chemical phenomena that may need to be considered in connection with the analysis of the growth processes of living cells. Aside from serving as simple illustrations of certain general phenomena that are apparently very roughly paralleled in the tissues of organisms, these artificial growths also furnish opportunity for the deeper study of the phenomena themselves. But it must always be borne in mind, in such studies, that the processes of enlargement

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[1] Pfeffer, W., Physiology of plants, translated by A. J. Ewart, vol. 1, p. 106. Oxford. 1900. For the original work on precipitation membranes, see: Traube, M., Experimente zur Theorie der Zellenbildung und Endosmose. Arch. Anat. Physiol. **1867**: 87–165. 1867.

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here encountered are not to be considered as the same as those called vital. Because a Traube's copper ferrocyanide cell enlarges in much the same *general* manner as does a germinating *Vaucheria* zoospore, this is not to be taken as evidence that the zoospore with its resulting filament is composed of a copper ferrocyanide membrane with a solution of copper salt on the inside! It is clear that the chemical substances involved in the living cells are entirely different from those of the artificial model, and yet the latter does unquestionably serve to illustrate some of the physico-chemical principles that are probably effective in cell formation.

Failure to emphasize this point in an adequate manner—the point that artificial precipitation cells are like living ones only with regard to the general nature of certain forces involved, and to certain superficial characteristics of their mechanical structure—seems to have been to blame for some features of the present attitude of cytologists toward the study of these artificial growths. Opposed on the one hand by the vitalists, with their slogan of *ignorabimus*, as far as the molecular physics and energetics of protoplasmic phenomena are concerned, and on the other by the extreme mechanists, who are forever attempting the explanation of protoplasmic phenomena in terms that are far too simple, the study of these interesting and suggestive processes has had but few followers. They lie in a realm still almost unentered either by physico-chemistry or by physiology. Such writers as Leduc,[2] for example, by emphasizing inordinately the likenesses and ignoring the unlikenesses between the "wonderful" phenomena of organic growth and the equally "wonderful" ones of physico-chemical growth, have done much to inculcate the current prejudice of biologists against this promising line of study.

On the other hand, the dense ignorance of molecular physics that still prevails among writers in experimental biology—the vagueness that remains evident in these circles, about osmotic phenomena, for instance—seems to render some acquaintance with the plant-like and animal-like growths of precipitation cells almost a prerequisite for constructive research in protoplasmic physiology. If the phenomena of cell growth in organisms are ever to be stated in physical and chemical terms, the principles to be worked out for artificial growths will surely be of great value in the formulation of such a statement.

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[2] Leduc, S., Théorie physico-chimique de la vie et générations spontanées. English translation by W. Deane Butcher, entitled The mechanism of life. New York, 1911. See also an article by W. Deane Butcher in Archives de Plasmologie Générale, Brussels, 1912.

The osmotic growths hitherto studied[3] have been of the form of closed tubes or cells, open to the outside only momentarily (as in the case of Traube's ferrocyanide cell), and their walls have been soft and unstable. They have been irregular in form, bending or breaking at points impossible to foresee; and it has been almost impossible to regulate the direction of growth and the production of branches, so as to make them capable of careful study. The osmotic growth about to be described is offered as a modification of those hitherto produced, which lends itself easily to regulation and to study. The tubes are of firm and stable composition, so much so, that specimens have been kept for eighteen months without change, and there is no reason to think that they may not be kept much longer. They are always open at the growing end and are filled with a watery solution. The diameter of the tube is nearly uniform throughout, and the direction of growth may easily be controlled by definite conditions in the surroundings. Except under certain definite conditions no branches are produced, but they may be produced at will. Unlike the growths hitherto studied, these may be grown to a great height, specimens nearly 2 meters high having been produced with ease; the limit of growth in these experiments is only the height of the available vessel. They are extremely sensitive to many variations in their surroundings and react to them promptly and definitely.

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[3] Böttger, R., Ueber Erzeugung Baum-und strauchartiger Vegetationen. Jour. Prak. Chem. **101**: 295–296. 1867.

Quincke, G., Ueber unsichtbare Flüssigkeitsschichten und die Oberflachenspannung flüssiger Niederschläge bei Niederschlagsmembranen, Zellen, Colloiden und Gallerten. Annal. Physik. 7: 589–631, 701–744. 1902.

METHOD AND OBSERVATIONS

The commercial solution of sodium silicate (specific gravity about 1:40) is mixed with a watery solution of sodium salicylate (concentration about 1:10), one volume of the salicylate solution to from ten to twenty volumes of the silicate solution; the solutions should be mixed gradually to prevent the formation of a coagulum. Fragments of potassium permanganate are dropped into the mixture thus formed, and the osmotic growth begins.

As soon as the fragment of $KMnO_4$ comes in contact with the liquid medium, some of the salt of course passes into solution. This solution is acted on by the medium and a precipitate (probably the oxides of manganese and silica) is formed around the fragment of the salt. This precipitate forms as a rather rigid layer or membrane, which constitutes the initial osmotic sac, and which bars the entrance of both the silicate and salicylate but allows the entrance of water. The exact nature of the chemical reactions by which this first membrane is formed and by which subsequent growth is accomplished has not been worked out, but the first step appears to be a reduction of the $KMnO_4$ so as to give manganese oxides and probably silica compounds. The action of the salicylate is not clear; it may be catalytic.

As water enters the sac, on account of the osmotic action of the saturated $KMnO_4$ solution within, additional quantities of the salt pass into solution. As long, therefore, as there remains a supply of undissolved $KMnO_4$ there can be no relief of the osmotic pressure, and the sac expands. Within a period of less than a second it becomes about a third larger than the original salt fragment (see fig. 1, A). The smaller sacs are either ovoid or spherical; the larger sacs are more nearly of the shape of the original crystal, but with rounded angles. The solution outside of the sac being of a higher specific gravity than that within it, the highest point of the sac becomes the point of least resistance, and the sac, having expanded to its full capacity, bursts open at this highest point. Through the rupture a stream of $KMnO_4$ solution pours forth and comes in direct contact with the surrounding medium. The process of growth proper now begins.

The opening in the sac, which is at first irregular, rapidly becomes round. It is then seen to be raised upon a protuberance which turns from a translucent red-brown (the color of the osmotic sac) to an opaque black. This protuberance becomes elongated into a stem whose thickness is uniform except at the end, where it tapers into a tall cone, open at the apex. This conical end of the stem retains throughout growth the translucency and red-brown color of the original protuberance. The entire process, from the moment the crystal is dropped into the medium until the formation of a perfect stem, occupies (at room temperature) about one minute.

The stem consists of an outer, a middle and an inner layer. During the process of growth no sharp line of demarcation can be seen between the solid tip of the stem and the solution in which it is bathed (see fig. 1, B). The first discoverable structure is at the upper edge of the inner surface of the stem and consists of minute refractive colorless spherical bodies which become irregular as they coalesce to form a continuous surface. This structure, which constitutes the thin lining of the lumen of the stem, may be observed in prepared microscopic specimens as a yellow band passing along the entire length of the stem. Where the refractive bodies have formed a continuous surface, this surface becomes covered externally with a translucent red-brown coating, which constitutes the thin outer covering of the stem. When fully developed this layer appears perfectly homogeneous. During the process of growth, however, it can be seen to be formed by the conglomeration of a vast number of minute spherical bodies of a red-brown color. Between these two layers a third, thin black layer, now makes its appearance, which thickens, until at the junction of the cone-shaped tip and the body of the stem, it outstrips in thickness both the inner and outer layers. The formation of the middle layer *after* the formation of the outer and inner ones accounts for a state of tension which exists in the outer layer. This tension is manifest from the fact that when a stem is removed from the solution, washed with water and dried, the outer layer bursts and peels off.

If it is wished to produce tall specimens, a glass tube 8–12 mm. is employed, and it should be slightly inclined, in order to permit the growth to approach the wall and climb along it. In such cases, too, the fragment of $KMnO_4$ (compressed tablets may be used) should be placed at some distance above the bottom of the glass tube. This may be accomplished in the following manner: Previous to filling the tube its wall is moistened with the solution at the desired point and the fragment applied. The salt will attach itself to the glass in a few seconds, after which the lower end of the tube is stoppered and the tube is filled.

Specimens for microscopic study are obtained as follows: Glass microscope slides are moistened with the solution and the fragment or fragments applied. The slides are then lowered into the solution in a slightly inclined position, the fragments being attached to their lower surfaces. When growth has taken place to the desired height, the specimens may be prepared in either of three ways. (1) The solution is permitted to dry upon the slides. In this case the stems will crack in a number of places, affording a view into their interior. (2) The slides are washed with water and the preparation is mounted in glycerinated gelatine. (3) The slides are washed with water and dried, after which the growths are brushed away. In the last case traces of the inner lining of the stems and of their outer covering adhere to the glass and give a very clear picture of their physical makeup.

The actual process of growth may be studied in two ways. Specimens may be grown in a very narrow space, as between a slide and a cover glass, joined by a frame of cardboard or paper. In this case the preparation is placed on the stage of the microscope inclined about 10 degrees from the vertical, in order to permit the growth to apply itself to the cover glass. The other way is as follows: The slide is moistened with the solution and fragments of the salt are strewn upon it. The preparation is then held over a vessel filled with water and a few drops of the prepared solution are placed upon it. After the desired amount of growth has taken place, the slide is lowered into the vessel, moved briskly, to wash off the solution, and allowed to remain in the water until all the $KMnO_4$ is washed out of the osmotic sacs. The preparation may then be mounted in glycerinated gelatine. A series of such preparations, with different amounts of growth, constitutes a consecutive record of the changes occurring in the process.

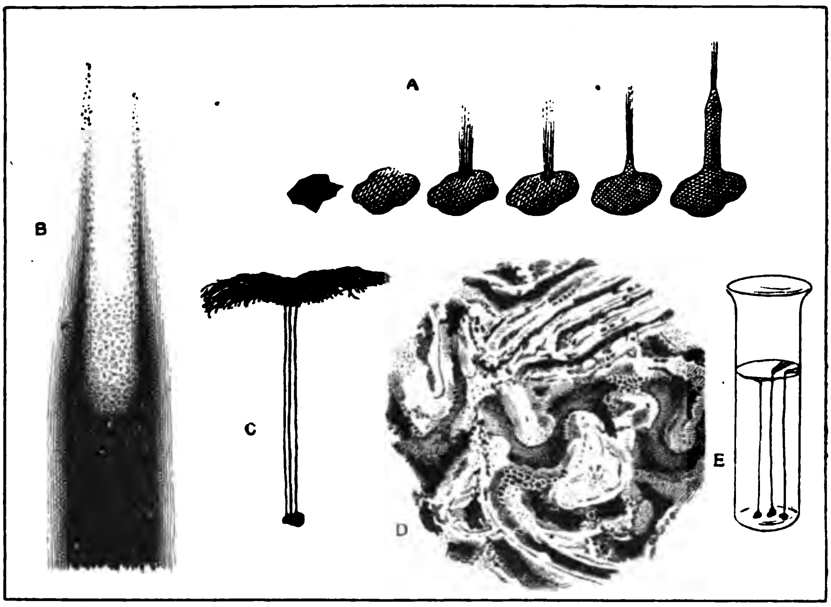

Fig. 1, A. Diagrammatic representation of various stages in the formation of osmotic sac and tube. B. Representing the manner of growth at the tip of the tube. Inside are shown small separate bodies, which became joined to form the inner layer. The middle layer is shown in black, and the outer by shading. C. General appearance of growth at surface of solution (floroid). D. Microscopic appearance of the central part of the floroid, showing the closely crowded open canals. Magnification 33 diameters. E. Bending of tubes toward wall of vessel and beginning of annular formation.

As long as the stem is immersed in the solution and there is a supply of $KMnO_4$ within, its upward growth continues. Arrived at the surface of the solution—not too near the wall of the vessel—a number of branches are formed, which grow horizontally in all directions, forming by their confluence a flattened cup with an irregular, fringed border. I have called this type of growth the floroid (see fig. 1, C). These horizontal tubes are open above, where they do not come in contact with the medium. In other words, the formation on the surface of the medium consists of a number of convoluted and anastomosing grooves and each groove is extended outward as one of the branches. All three layers of the stem are represented. The middle and outer layers are, however, much thicker than in the stem, especially toward the center of the cup. In that situation the outer coats of neighboring canals coalesce, and the appearance is that of a solid surface traversed by grooves (see fig. 1, D). The diameter of the structure varies with the number of stems participating in its formation. A single stem may produce a floroid as large as 2.5 cm. in diameter.

When the upward-growing stem reaches the surface of the solution near the wall of the vessel, it divides into two or more branches, which proceed horizontally toward the wall, at which point each branch bifurcates (see fig. 1, E and fig. 2, A and A′). The new branches grow along the wall, in opposite directions, at its junction with the surface of the liquid, until they meet again at the opposite side of the vessel. The ring thus formed continues to thicken until growth ceases. This ring-like growth consists of a number of parallel canals situated at different levels, and in cross section has the appearance of a honeycomb (see fig. 2, B). I have called it the canalicular formation.

While the stem is immersed in the medium, the surplus of $KMnO_4$—that part not used up in the growth of the stem—escapes from the open tip of the stem, is partly reduced, is changed in color to a red-brown solution, and rises to the top. When the stem has reached the top of the medium, however, this surplus accumulates unchanged, either upon the flat cup of the floroid or within the parallel canals of the annular formation. The surface structure may therefore be removed from the vessel and dried, after which it may again be placed in the solution, with the result that new stems sprout forth from it and the whole process is repeated. As the $KMnO_4$ is more protected from contact with the medium in the canalicular formation than upon the floroid, the former produces the more certain re-growth.

After a well-developed surface growth has formed, if a fresh supply of medium is poured into the vessel, new stems regularly sprout forth from the old surface formation thus submerged. By adding solution each time to the height of only 2 or 3 cm. in a test tube, it is possible to produce a number of surface formations, both canalicular and floroid, one mounted upon the other (see fig. 2, C).

A structure resembling the floroid described above may be obtained on a glass slide. Crystals are placed upon the bottom of a suitable vessel, brimful of the medium, and the stems are allowed to grow upward, toward the surface, in the usual way. The glass slide is laid across the top of the vessel, thus being in contact with the solution. Upon reaching the surface of the slide, the stems branch out laterally and continue to grow on the glass to which they adhere. The slide may be removed, and the preparation thus obtained may be treated like the slide preparations described above.

As the stem grows upward, in the regular way, it is observed that a brownish fluid continuously issues from its tip, rises, and becomes dispersed in the upper layer of the medium. If part of the medium be removed so as to expose the stem for a centimeter or two, and if water is then added until the stem is once more covered, it is observed that instead of the brownish fluid a clear solution of $KMnO_4$ issues from the tip of the growing tube. At the same time growth is suspended. If the tip of the stem be exposed and a glass capillary tube be placed over it, the glass tube soon fills with a concentrated solution of $KMnO_4$. When the stem is grown in a space about 0.1 mm. in width (somewhat less than the diameter of the stem), as between a slide and a cover glass joined by a frame of cigarette paper, the opposite sides of the osmotic growth—those in contact with the glass—are imperfect. It can then be plainly seen that the canal of the stem is filled with an upward flowing solution of $KMnO_4$, and that the solution, as it issues from the tip of the stem and comes in contact with the reducing medium, turns brown.

As growth proceeds, the upper layer of the medium becomes thin and about the color of port wine. The salt is dissolved in the water taken up by the osmotic sac, and propelled upwards to the growing tip of the stem. There part of the salt in solution is used up in growth, and the remaining dilute solution is set free and, partially reduced, rises to the top of the medium.

INFLUENCE OF INTERNAL AND EXTERNAL CONDITIONS UPON THE RATE OF GROWTH

The stem varies in thickness from 0.24 to 0.12 mm. The diameter of its lumen is from 0.08 to 0.04 mm. The height of the stem depends upon the total amount of $KMnO_4$, upon the height of the column of liquid within the container, and upon the amount of water available for bringing the salt into solution within the osmotic sac. For some time it seemed impossible to grow stems taller than about 38 cm. Upon investigation it was found that after some hours of growth the osmotic sac, resting upon the bottom of the vessel, became surrounded by a highly concentrated zone of the colloid solution. Water had been taken up by the sac from the solution immediately surrounding it, and, the supply of water having become exhausted, growth of the tube above had been stopped. This condition was obviated when the crystal was supported at some distance above the bottom of the vessel. The concentrated zone of the colloid solution being of a higher specific gravity, then sank to the bottom and was replaced by fresh solution of a lower specific gravity. Specimens have thus been grown nearly 2 meters high, in glass tubes, as has been mentioned.

The rate of elongation of the stem is greatly influenced by temperature. Chemical processes are more active, and the osmotic pressure of a substance in solution increases, as the temperature rises. These facts partly explain the relation. Thus while growth is more active at the tip of the stem with every rise in temperature, a greater supply of $KMnO_4$ is at the same time furnished by the increased osmotic pressure of the $KMnO_4$ solution within the canal of the stem and the osmotic sac. At a temperature of 0°C. the stems grow at the rate of 2.5 cm. in ten hours. At 42°C. they grow at the rate of 2.5 cm. per hour during the first twenty-four hours and at the rate of 30 cm. per day during succeeding days.

Growth is more rapid when the stem clings to the side of the vessel than when it is surrounded on all sides by the solution. The vessel wall (or glass plate, etc.) supports the inner layer of the stem as it is formed. The outer and middle layers are not then formed, as has been remarked; that is, the side of the stem in apposition to the solid surface is imperfect. Thus not so much $KMnO_4$ is used in forming the wall, and a more rapid rate of growth is the result. When stems are crowded in a limited space to the extent of interfering with each other's growth, this factor—the economy of substance—makes for the persistence of the stems situated in apposition to a foreign body, at the expense of others, which cease growing. This question will be further discussed under a separate heading.

Rapidity of growth being in direct proportion to the degree of osmotic pressure within the sac, it is necessarily less rapid when a number of stems arise from the same sac than when only a single stem is formed.

DIRECTION OF GROWTH

When the conditions of the environment are the same on all sides of the stem, its direction is vertically upward, this being due to the fact that the solution within is less dense than the surrounding medium. If, in the course of growth, the vessel be tilted, turned on the side, etc., the stem bends and still proceeds to elongate upwards. In this manner a stem may be made to assume almost any linear figure (see fig. 2, D). If a horizontal obstacle be placed above the vertically growing stem, the latter will branch out laterally along the under surface of the obstacle, until one of the branches will have reached its edge, when it will continue vertically upwards again.

When the stem is surrounded on all sides by the solution, it is rarely perfectly vertical. This is due to the extreme sensitiveness of the stem to differences in temperature on opposite sides. After the stem has been formed, it does not respond to temperature differences, but the new increments of the growing stem are added so as to produce a bending toward the warmer side of the container. Stems were grown in rectangular vessels 25 by 15 by 3.75 cm. The broad sides of the vessels were of glass, the narrow sides of tin. In such vessels heat conduction

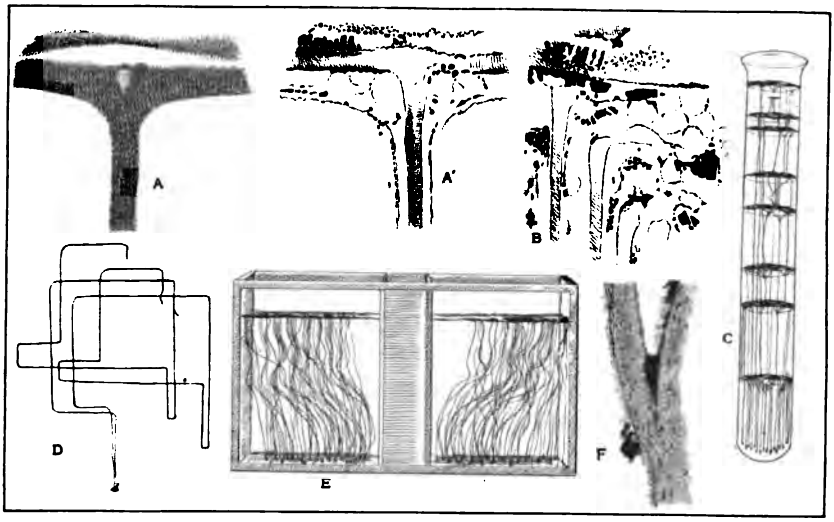

Fig. 2, A. Microscopic appearance of beginning of annular formation. A. A stem bifurcating into two horizontal branches at junction of glass slide and top of solution. A′. the interior of A. The glass slide upon which the specimen was grown was first photographed, then the growth brushed away and the slide photographed again. Magnification 24 diameters. B. A canalicular formation in cross section. The lining of vertical canals of stems and openings of horizontal canals only appears, the opaque parts of the growth having been brushed away before being photographed. Magnification 24 diameters.

C. Repeated canalicular formations, one above another. The lowest is allowed to form at the surface of the solution, then more solution is poured in, a second is allowed to form, etc. D. A linear figure produced by turning the glass plate, to which the growth adheres, a number of times in the solution. E. The effect of heat upon the stems. Actual size 25 by 15 by 3.75 cm. The broad sides of the vessel are made of the glass, the narrow sides, the bottom and the chimney passing through the center are made of tin. A small flame burned in the chimney while the stems were growing. F. Showing the thickening of the stem below an outgrowing branch and its bending in a direction opposite to the side from which the branch arises. The lining of the canals only is shown, the opaque parts of the stem having been brushed away from the glass slide. Magnification 100 diameters.

is greatest along a line of the long diameter. To produce vertical stems in such vessels, in the winter, in a room heated in the ordinary manner, is impossible. The inclination of the stems in such cases is always toward the source of heat in the room. A vessel of the type above described was placed under conditions where the temperature on all sides of it were as nearly equal as I could make them. The room (in the winter) was unheated, and the vessel, well isolated with towels, was placed in the central compartment of the bottom drawer of a desk and left there undisturbed overnight. In the morning it was found that the stems were inclined toward a vertical line passing through the center of the vessel. The temperature of the room had fallen during the night, while the stems were growing, a little over one degree, and the center of the vessel has therefore become the warmest point.

The direction of the stems is, however, not continuously toward the warmer side. It is at first toward, then away from it; then again toward, then again away; and so on in a series of upward curves. Stems were grown in a vessel of the type described above, except that it had a tin chimney passing vertically through its center, in which was placed a small flame. The result was a series of regularly symmetrical curves on each side of the chimney, as will be seen in figure 2, E. So far I have no adequate explanation to offer for the formation of these curves.

When the stem has reached the top of the solution, and the source of heat is definite, as from a Bunsen burner, the direction of horizontal surface-branches is definitely toward the warmer side of the vessel.

A similar bending toward the source of strong illumination is also observed, but this may be another instance of heat effect.

THE PRODUCTION OF BRANCHES

When the stem has been compelled, by the turning of the vessel, to make a number of sharp bends, it ceases to grow. Instead a new stem shoots out either from the osmotic sac or from the side of the old stem. It has already been remarked that the interposition of a horizontal obstacle in the course of the vertically growing stem produces a branching of the stem on the lower surface of the obstacle. These branches pass laterally in all directions until at least one of them reaches the vertical side of the obstacle, when it will continue upwards, while the rest of the branches stop growing. If the tip of the stem is covered with wax, or some other material so as to close up its opening, it stops growing. In a few seconds, however, it is found that a new stem grows either from the side of the old stem or from the osmotic sac. If the tips of the branches are in their turn closed up with wax, new branches shoot out either from the old branches, from the main stem, or from the osmotic sac. In this manner any number of branches can be produced at will.

When a branch grows from the side of the stem, the part of the stem between the osmotic sac and the branch, thickens and bends in a direction opposite to that where the branch arises (see fig. 2, F). A breach in the weakest point of the stem wall, or sac, consequent upon the rise of pressure within the stem and sac when the outlet is closed, explains the growth of branches under these conditions. The pressure of the fluid within the stem must rise when it is bent at sharp angles a number of times, and this condition, too, accounts for the outgrowth of branches. The same increase of pressure within the stem, forcing the permanganate solution through its wall, possibly accounts for the thickening of the stem between the sac and the outgrowing branch. The wall of the stem opposite to that from which the branch grows, must be subjected continually to greater pressure from within than that which bears the branch (the latter having an outlet, the former having none—the principle of the revolving garden-sprinkler), and this fact may account for the bending of the stem between the sac and the branch in a direction opposite to that from which the branch grows. Thus it apparently happens that the same factor which causes the outgrowth of a branch (the rise of osmotic pressure within) also, enables the stem to withstand the increased weight occasioned by the new outgrowth.

REACTIONS OF THE GROWTH TO UNFAVORABLE CONDITIONS

When the fragment of $KMnO_4$ is dropped into the solution, it is seen that one or more gas-bubbles adhere to it. Microscopic observation reveals the fact that a gas-bubble always appears in the situation where a stem is about to sprout forth (see fig. 3, A). Not infrequently it happens that this gas-bubble is caught in the open tip of the stem (see fig. 3, B1). Growth takes place around the gas-bubble, the stem showing a protuberance in that point, the wall of which is sometimes thinned out so that the bubble can be plainly seen through it (see fig. 3, B2). If sufficient space is left between the inner wall of the stem and gas-bubble for the free onward-flow of the solution within, no other reaction occurs (see fig. 3, B4). If the space is too narrow, a branch shoots out from the stem (see fig. 3, B3).

At a temperature of about 56°C. the fluid within the tip of the stem coagulates. The pressure within the stem forces out this coagulum, which appears in the form of a fine, convoluted thread about the upper part of the stem. The increased pressure within the stem, however, soon causes the outgrowth of branches. The coagulation of the fluid within the tips of these branches results in the outgrowth (from the branches) of finer branches. The finer branches, in their turn send out still finer branches, until the growth appears like a thick mass of matted threads (see fig. 3, C).

When a stem is entirely broken off, a new conical tip rapidly forms upon the stump and growth proceeds as before. Advantage was taken of this fact to obtain successive crops of stems without replanting the crystals, until the osmotic sacs were exhausted of the contained $KMnO_4$. A somewhat modified reaction occurs when the stem is broken so as to retain the broken part on a line with the stump. The latter may be accomplished in the following manner: Stems are grown upon glass slides, as directed above. When grown to some length, they are cut across with a knife and the slides again immersed in the solution, as far as possible in the same situation as before. A few minutes after the cut stems have been immersed, it is found that the loss of substance has been bridged over by new growth and that the stems are much thickened in that situation. Examination of the interior of this thickening shows two canals (see

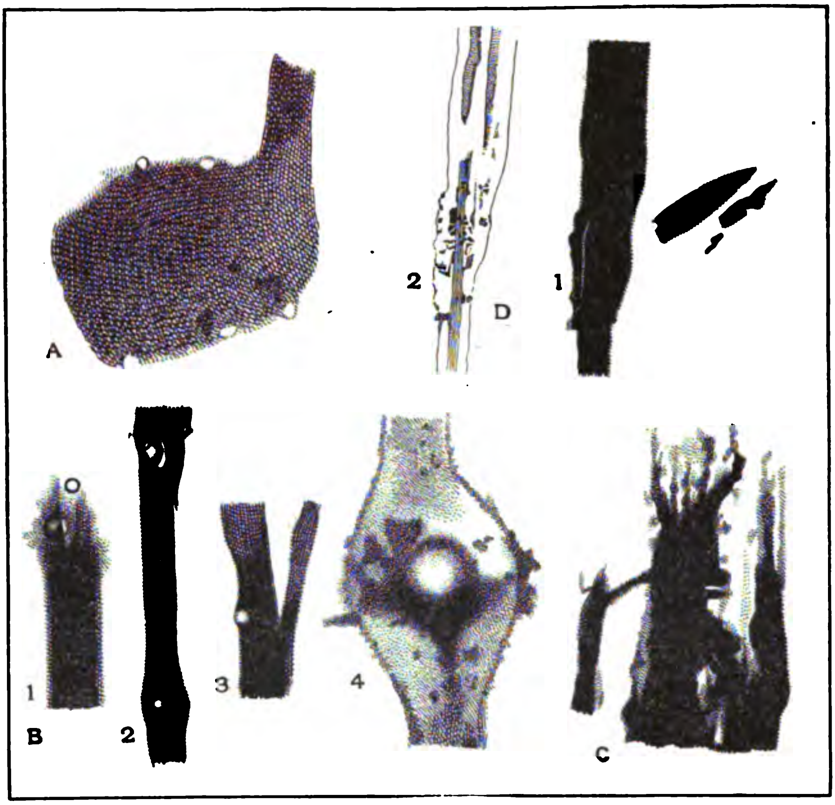

Fig. 3, A. A sketch from a photograph of an osmotic sac. Gas bubbles are seen to adhere. Below and to the right is seen an aborted beginning of a stem enclosing a gas bubble within its opening. Fig. B. Sketches made from photographs. *1*, Gas bubble caught in the open tip of the stem. *2*, The thickening of stem at the point where the gas bubble is held. *3*, The outgrowth of a branch beneath the obstructing gas bubble. *4*, The lining of the canal of the stem enclosing a gas bubble. Magnification of *1*, *2*, *3* 36 diameters, magnification of 4 150 diameters. C. The effect of high temperature upon the osmotic growth. D. Showing a thickening at the point where repair has taken place after fracture. The black patches to the right of *1* are chips from the fracture which adhered to the slide while it was photographed. *2*, The interior of *1*, showing the exact site of fracture where the canal is interrupted. The new canal arises from the side. Magnification 36 diameters.

fig. 3, D). The old canal is on a line with the stump, the new somewhat to the side. Further growth is along the line of the latter canal.

When the medium is too thin, the osmotic pressure within the stem forces the $KMnO_4$ solution through the wall of the stem, with the result that the latter becomes surrounded by a brownish precipitate. Growth under these conditions is tardy, the stems remaining stunted.

MUTUAL INTERFERENCE

A number of osmotic growths crowded together in a limited space, affect each other's growth in several interesting ways. To elucidate the facts in this connection, a series of experiments was carried out, as follows: Various numbers of fragments of $KMnO_4$ (as nearly as possible of the same size) were planted in test tubes (also of the same size), filled with the solution to the same height, and placed as far as possible under the same conditions of temperature, etc. After a certain number of hours the solution in the test tubes was replaced by water and the stems grown were counted and measured (through the glass). Following are two typical tables of the results obtained.

TABLE 1

Stems were permitted to grow for eight hours in six test tubes, each 20 cm. in height and 1.5 cm. in diameter, with the following results

NUMBER OF FRAGMENTS OF $KMnO_4$ IN TEST TUBE	NUMBER OF STEMS GROWN IN TEST TUBE	RESPECTIVE LENGTHS OF STEMS (IN CENTIMETERS)	NUMBER OF STEMS PER FRAGMENT	TOTAL STEM-LENGTH IN TEST TUBE.	TOTAL STEM-LENGTH PRODUCED BY AVERAGE FRAGMENT	LENGTH OF THE LONGEST STEM	LENGTH OF THE SHORTEST STEM
				Centimeters			
1	3	11.8, 5.6, 2.5	3.0	19.9	19.9	11.8	2.5
2	4	11.25, 10.6, 9.3, 6.25	2.0	37.4	18.7	11.25	6.25
3	6	13, 12, 8.5, 8.5, 5.6, 2.5	2.0	50.1	16.7	13.0	2.5
4	9	11.5, 10.5, 8.75, 8, 6.5, 6.8, 5.5, 2.5, 2	2.25	62.05	15.51	11.5	2.0
5	9	12.8, 11.5, 11, 10, 6.5, 6.5, 6, 6, 1.8	1.8	72.1	14.4	12.8	1.8
10	13	12.5, 10.6, 9.5, 8, 7, 7, 7, 7, 5.6, 5, 3, 2, 1	1.3	85.2	8.52	12.5	1.0

A study of table 1 shows that, on the whole, there is a disproportion between the number of fragments of $KMnO_4$ planted in each test tube and both the number of stems and the total stem-length (the sum of the lengths of all the stems in the test tube) produced; that while the single fragment in the first test tube had produced 3 stems—had produced a total length of growth of 19.9 cm.—a similar fragment in the last test tube had produced only 1.3 stems of a total length of only 8.52 cm. On the other hand the table shows that notwithstanding the total diminution of the product as the crowding of the fragments increases, taller specimens are, on the whole, to be found there than where the crowding is least; and in contrast to this, the shortest specimens as well are found where the crowding is greatest.

TABLE 2

Stems were permitted to grow for twenty-five hours in 12 test tubes, each 35 cm. in height and 2.5 cm. in diameter. The test tubes were filled to within 2.5 cm. from the top.

Number of fragments of $KMnO_4$ in test tube	3	6	9	12	15	18	21	24	27	30	33	36
Number of stems which arrived at the top of the solution	0	1	1	3	4	4	4	3	8	7	8	9
A canalicular formation completely (C) encircles the wall of the test tube at its junction with the top of the solution, or, (I), incompletely	0	I	I	C	C	I	C	C	C	C	C	C

Table 2 shows that the chances for re-growing the stems from the $KMnO_4$ deposited at the surface of the solution are greater where the crowding of the fragments is greatest. Of the stems grown in the test tube containing three fragments of $KMnO_4$, none reached the top of the solution, consequently no canalicular formation was produced, and therefore no $KMnO_4$ was deposited. The canalicular formations in the test tubes containing a fewer number of fragments, are, on the whole, incomplete, and therefore contain less $KMnO_4$ than the complete canalicular formations in the test tubes containing a larger number of fragments.

To sum up. Crowding affects the growth in the five following ways: (1) By a diminution of the number of stems produced by the average fragment of $KMnO_4$. (2) By a diminution of the total length (the sum of the lengths) of the stems produced by the average fragment. (3) By the appearance of very tall specimens. (4) By the appearance of very short specimens. (5) By a larger deposit of $KMnO_4$ within the surface-canals. There is a sixth way, which does not appear from the tables. The stems, with the exception of the very tall ones, are not as clear-cut and regular where the crowding is beyond a certain point. They are matted together; they cling to and twine around each other.

The circumstances which, when the growths are crowded, result in the better development of a few at the expense of the greater number, may be summed up briefly as follows:

1. A situation of the fragment of $KMnO_4$ where a large area of its surface comes in contact with the medium. As the osmotic sac continually dehydrates the medium, and becomes surrounded by a concentrated zone of the colloid solution, the higher it is situated above the bottom of the vessel, the better will be the growth. For the concentrated solution around the osmotic sac being of a higher specific gravity, continually falls downward and is replaced by a solution containing a larger amount of water upon which the osmotic sac draws for its supply.

2. A situation of the fragment near the wall of the vessel. As has been remarked, the apposition of the stem against a foreign body makes for economy of substance, and the less substance is required to form it, the faster will it grow. Owing to the fact that the stem grows towards the warmest point, the shape of the vessel and the material of which it is made will have a bearing in bringing a stem to or away from the vessel-wall. When a stem is situated on the cooler side of a circular vessel, made of a poor heat conductor, such as glass, it will move toward the center of the vessel, where the heat-rays are focussed. When a stem is situated, on the other hand, near the warmer side of the vessel, it will approach the wall, cling to it, and proceed to grow at an advantage.

3. When the solution is poured upon the crystals, or when the crystals are thrown into the solution, they become necessarily somewhat displaced from the position assumed by them upon their first contact with the liquid. The manner in which this displacement occurs will have a bearing upon the persistence of some of the stems and the cessation of growth of others. Growth begins immediately upon contact of the $KMnO_4$ with the medium. If, now, after stems have sprouted forth from the fragment, the fragment becomes displaced, the stems which arose originally from its highest point, come to arise from its sides or bottom, and must make an abrupt bend in order to proceed upward. If the bend is too abrupt, the increased pressure at the highest point of the osmotic sac will cause a rupture, with the consequent outgrowth of a stem. The flow of the $KMnO_4$ solution being unimpeded within the lumen of this stem, it will grow faster than the older, bent stems. The flow of the fluid within the more advantageously situated stem moreover, accumulates momentum under the incident force of the osmotic pressure at the expense of the flow of the fluid within the less advantageously situated stems. The stagnating $KMnO_4$ solution in the open tips of the latter stems becomes reduced by contact with the medium, clogging their openings with the precipitate formed, with the cessation of growth of these stems as the result.

4. When several fragments of $KMnO_4$ lie close together in the solution, they adhere to each other and form one sac partitioned on the inside into as many compartments as there were fragments. The $KMnO_4$ of those compartments from which no stems grow, or those whose stems have ceased growing, serves as a supply for the growth of the more advantageously situated stems. Thus not only does the better situated fragment produce the taller growth, but the growth which it produces is at the expense of the worse situated fragments.

CONCLUSION

In conclusion it should be again remarked that the resemblances between this osmotic growth and the growth phenomena of living things are very grossly superficial. The phenomena of these precipitation tubes are of interest mainly because they lead to a kind of physico-chemical thinking that is surely required in the analysis of many physiological processes. If it is worth while for the beginner in cell physiology to attempt to interpret the behavior of Traube's artificial cell, it is perhaps worth while for him also to see this other form of artificial growth.

SOME UNDESCRIBED PRAIRIES IN NORTHEASTERN ARKANSAS

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College Point, New York

In The Plant World for February, 1914, attention was called to the large prairies in the alluvial region east of Little Rock, Arkansas, which seem to be unique in several respects. In the latter part of August, 1915, while spending a few days in Craighead County, 80 or 90 miles northeast of the prairies previously described, I was shown some smaller prairies in the same general region (the coastal plain west of Crowley's Ridge), which may have had a similar origin, but differ considerably in their vegetation from those of Prairie and adjoining counties.

The first (fig. 1) is about a mile and a half southwest of Gilkerson (a station on the Cotton Belt Route at the foot of Crowley's Ridge), and is an opening in alluvial hardwood forests, covering only a few acres. The vegetation is fairly dense and about knee-high, but the flora is very meager, the only plants identified at the time being *Crotonopsis linearis* and *Ambrosia bidentata*, with a sprinkling of *Vernonia fasciculata* (?), *Baptisia leucantha* (?), *Aristida* sp., *Fimbristylis autumnalis*, and *Diodia teres*. Scattered around the edges of the opening, and showing plainly in the illustration, are trees of *Quercus palustris*, while a little farther back in the forest *Quercus pagodaefolia*, *Ulmus alata* and *Quercus Phellos* prevail. Grasses, and plants with wind-distributed seeds, are much scarcer than in the average prairie, and the mode of dissemination of the two commonest herbs is not certainly known. Fire is probably a rare occurrence here. In Georgia the *Crotonopsis* is chiefly confined to rock outcrops, where fire is almost impossible, and the *Diodia* is also found in similar habitats, though more common as a roadside weed.[1]

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[1] In this connection see Bull. Torrey Bot. Club **40**: 390 (footnote). August, 1913.

About 9 miles southwest of Jonesboro (the county-seat) a considerably larger prairie, perhaps fifty acres in extent (fig. 2), with similar surroundings but much richer flora, was visited the next morning, but rather hurriedly, for the man who took me there in his automobile had to be in his office in Jonesboro by 8 a.m. The following plants were noted, the herbs being arranged in approximate order of abundance:

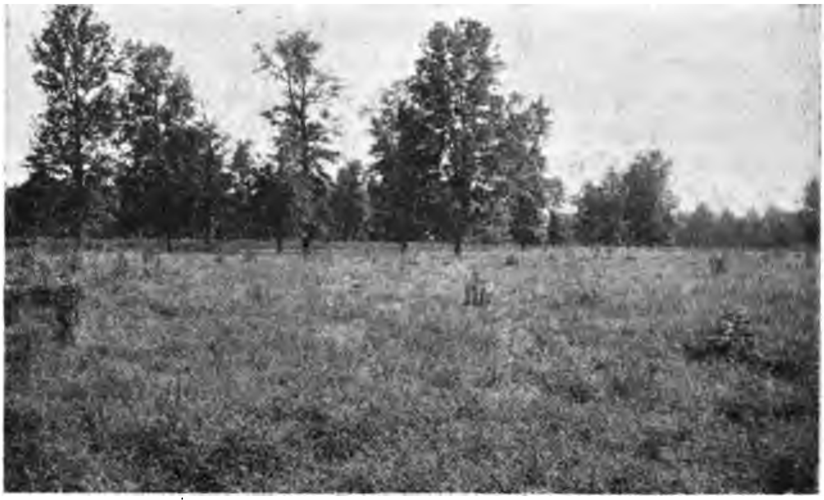

Fig. 1. Small prairie near Gilkerson, Arkansas. The trees are mostly *Quercus palustris*. August 24, 1915.

TREES

Quercus palustris (around edges)

SHRUBS

Sassafras variifolium
Rhus copallina

HERBS

Ambrosia bidentata
Laciniaria scariosa
Crotonopsis linearis
Sarothra Drummondii
Vernonia fasciculata?
Baptisia leucantha?
Chamaecrista fasciculata
Panicum virgatum
Panicum capillare?
Paspalum sp.
Diodia teres
Euthamia sp.
Eupatorium semiserratum?
Cracca Virginiana
Boltonia diffusa
Juncus brachycarpus
Morongia sp.
Lespedeza Virginica?
Aristida gracilis?
Laciniaria spicata?
Cuscuta sp.
Buchnera elongata
Galactia sp.

This vegetation is more like that of the Grand Prairie of Prairie County, and if that region were visited at the same season probably nearly all these species could be found there. Plants with wind-borne seeds are evidently more abundant here than in the small prairie first mentioned, a fact probably correlated with the larger size of this one, which exposes it more to the wind. Some of the plants in the last list have thick rootstocks or corms, and probably would not be injured by an occasional fire; and it is very likely that the frequency of fire in prairies is roughly proportional to their size. No estimate of the bulk of the vegetation per unit area was attempted at the time, but from comparisons with other types of herbaceous vegetation that have been studied since I should judge that it would produce at least three or four tons of hay per acre annually.

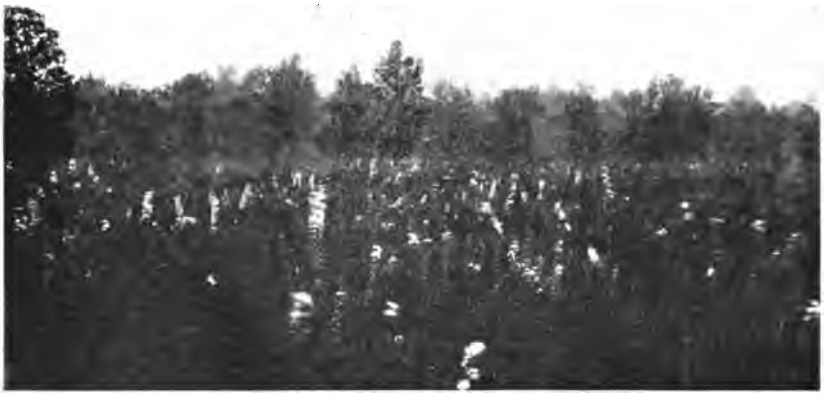

Fig. 2. Prairie about 9 miles southwest of Jonesboro, Arkansas. *Laciniaria scariosa* conspicuous in foreground. August 25, 1915.

Although the soil is of a comparatively recent alluvial formation, the area is not subject to overflow now, and it may have experienced a slight uplift at a very recent geological epoch. A mile or two from the larger prairie, and apparently on the same level, is a roadside gully about five feet deep, showing about two feet of brown silty loam resting on stiff mottled clay. The soil looks fertile enough, but there must be something about it unfavorable to vegetation, for I was told that the farmers were not able to make any use of it until rice culture was introduced in this section a few years ago. Rice fields now threaten the obliteration of these prairies, as of the Grand Prairie.

There are probably other prairies in the neighborhood, and an early investigation of them is greatly to be desired, for the opportunities are growing less every year, on account of the "pernicious activities" of the farmers. The colored map in Bulletin 494 of the United State Geological Survey, and some of the recent government soil surveys of counties in northeastern Arkansas and southeastern Missouri, will assist materially in locating them.

BOOKS AND CURRENT LITERATURE

Field Study of Osmotic Concentration.—Whenever a step is taken which makes it possible to secure data on any aspect of the physiological behavior or condition of plants under field conditions, an important contribution is thereby made to the advancement of plant ecology in one of its most important and fruitful directions. The technique which has been worked out by Harris for securing the sap of plants and determining its freezing point has been simplified and perfected in such a manner that he has been enabled to secure a very considerable quantity of data on the osmotic concentration of plant saps. Following a preliminary paper in Science[1] Harris, Lawrence, and Gortner have published the results of their determinations of concentrations for plants growing in the vicinity of Tucson, Arizona.[2] From one to four sets of determinations were made for each of some 124 plants, and figures are published for the depressions of freezing point and for the osmotic concentrations in atmospheres. The work was done in March and April, when vegetative activity is high and the moisture content of the soil is neither at its highest nor its lowest values for the year. Plants of every vegetative type were used, and sets of determinations were secured in five localities which differ in the physical and moisture conditions of the soil. Sap was secured only from the leaves, and usually from plants in flowering condition. The lowest values were secured in the annuals, *Calyptridium* exhibiting 8.3 atmospheres, *Calycoseris* 9.1, *Parietaria* 9.5, and *Galium* 9.6; and in the climbing root-perennial *Cissus*, which exhibited a value of 8.6 atmospheres. High values were secured for the leguminous tree *Olneya*, 29.7, for *Covillea*, 34.2, for *Yucca*, 37.4, for the buxaceous shrub *Simmondsia*, 40.6, for *Atriplex* growing in a salt spot, 52.0, and for the evergreen celastraceous shrub *Mortonia*, 57.2. A comparison of the various vegetative types of plants shows that the trees and shrubs have, in general, a higher sap concentration than the dwarf shrubs, and the latter a higher concentration than the annuals and root-perennials. The only true trees worked on were *Olneya*, which grows away from water courses, and shows a concentration of 29.7, and *Fraxinus*, which grows only near streamways and shows a concentration of 16.7 to 19.6. The semi-succulent *Dasylirion* has a concentration of 35.0 and the leaf-succulent *Agave* of 11.1, while the deciduous *Fouquieria* varies from 10.4 to 14.4.

---

[1] Harris, J. A., Lawrence, J. V., and Gortner, R. A. On the osmotic pressure of the juices of desert plants. Science, **41**: 656–658, 1915.

[2] Harris, J. A., Lawrence, J. V., and Gortner, R. A. The cryoscopic constants of expressed vegetable saps, as related to local environmental conditions in the Arizona deserts. Physiol. Res., **2**, No. 1, pp. 1–50, 1916.

The material used by Harris and his collaborators was taken in five habitats differing in physical conditions and in vegetation. These were the floor of a cañon, the rocky slopes of a hill, bajada slopes (tilted detrital plains), a sandy arroyo, and a salt spot. The osmotic concentrations were averaged for all of the plants of each vegetative type that were gathered in each habitat. These are lowest for the arroyo, slightly higher for the cañon, still higher for the rocky slopes, again higher for the bajada, and highest for the salt spot. These results indicate that there is an appreciable difference in sap concentration for each type of plant in each of these habitats, which are among the most marked that may be seen at desert elevations in the Tucson region.

However much the extraction of sap by Harris's method may obscure the conditions under which many of the foliar functions are carried on, it gives nevertheless a means for securing an average expression of the physico-chemical condition of the juices of the plant, which he terms "both the product and the environment of the activities of the protoplast." However much our conception of the importance of osmotic phenomena in plants may be modified by the results in colloidal chemistry which are now beginning to accumulate, nothing can minimize the importance of the physico-chemical condition of the sap of plants as related to environmental conditions, and particularly to the intake and loss of water. The facts that Harris's results are accordant with our knowledge of the physical conditions of the habitats in which he worked, and with what we know of the seasonal behavior of the plants which he used, are in themselves a confirmation of the physiological soundness of his work, as well as a stimulus to the study of physiological phenomena in connection with field work. The results that have been secured by Harris in his subsequent work in Florida, Jamaica, and Arizona will be awaited with interest.—FORREST SHREVE.

GERMINATION AND EARLY GROWTH OF FOREST TREES.—In a recent paper[1], Boerker presents what is perhaps the first American publication on the scientific side of forest nursery practice, the work being based on the greenhouse germination and growth of many American forest tree species. The work is divided into three parts: the effect of habitat factors on germination; the effect of habitat factors on stem and root development, and the relation of the size of seed on germination and development.

The author finds that from the germination in three different soil moistures he is able to divide the trees of each region into three classes. The xerophilous species germinated in all three soil moistures, the xero-mesophilous group in the two moister soil cultures, and the mesophilous species germinated only in the soil containing the most moisture. In general, the drier the soil the longer germination was delayed, though the total length of the germination period is decreased as is the final germination per cent. Shade affected the germination by decreasing the time necessary for its initiation and by increasing the length of the germinating period. In all three groups germination began first in the dense shade and last in full light with the longest germinating period and highest germination per cent in the dense shade. Sand gave a more rapid germination, a higher final germination per cent, and a longer period of germination than did either gravel or loam. Sand and gravel accelerate germination while loam retards it, due more to the lack of oxygen than to a difference in soil moisture. The larger sized seeds of *Pinus ponderosa* and *Pseudotsuga taxifolia* gave a higher germination per cent and produced larger seedlings than did the smaller sized seeds. From east to west, the seeds of these species germinated earlier, the rapidity factor was greater and the germination period was shorter, while in the case of *P. ponderosa* the size of the seed increased.

In this discussion of the habitat factors on stem and root development, the author brings out no points that are unfamiliar to the forest nurseryman and practitioner, and the results attained with four species are too conflicting for definite conclusions. While the work is interesting from many standpoints to foresters and well worth a perusal by students of plant life the data are too meager and the number of seeds on which the work is based too few, especially in such species as *Libocedrus decurrens*, to eliminate errors and to warrant adopting *in toto* the conclusions which are brought forward. The germination curves which accompany the text are very instructive.—EDW. N. MUNNS.

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[1] Boerker, Richard H., Ecological Investigations upon the germination and early growth of forest trees. Diss. Univ. Neb. Lincoln, Nebraska, 1916.

NOTES AND COMMENT

The navel or seedless orange, which is so extensively grown in California, has been in existence little more than a hundred years, and its cultivation in this country can be traced to several small saplings brought from Brazil only forty-five years ago. A recent study of the fruit made in its native home near Bahia, Brazil, by representatives of the Department of Agriculture, has eliminated much of the mystery that surrounded its introduction into the United States and has added much interesting knowledge in regard to its origin and its present culture. The results of this study have recently been published as Department of Agriculture Bulletin 445. The evidence points to the fact that the variety of navel orange grown in this country first came into existence near Bahia early in the nineteenth century, as a sport from the Selecta orange. The latter variety is still grown extensively in Brazil, and some of the trees show a marked tendency at times to produce fruit with well-developed navels. Almost the entire present planting of navel oranges in California can be traced directly back to two of the trees sent there by Mr. Saunders in 1873, from stock secured by a missionary in Brazil. The navel orange as it occurs near Bahia is large, varying from 3½ to 4 inches in diameter, is yellow green in color, and extremely juicy and sweet. The Brazilian fruits have a considerably lower percentage of peel than the California fruits and somewhat less fibrous matter or "rag." The California orange, however, has a much larger percentage of both citric acid and sugar.

The forested portions of the public domain of New Zealand are administered by the Department of Lands and Survey, with an approximate expenditure of £40,000 per annum and an income which has fluctuated in recent years between £30,000 and £60,000 per annum. No definite forest policies have been formed and there are no trained foresters in the service of the Dominion. At a meeting of the recently formed New Zealand Forestry League an address was made by Mr. D. E. Hutchins, in which the forest conditions were described and a plea was made for the early establishment of a department of forestry under thoroughly scientific management. The substance of this address, together with much interesting information about New Zealand's forest resources, was published in recent numbers of the Journal of Agriculture. Mr. Hutchins has been engaged in practical forestry work in British possessions for over forty years. He was engaged in the demarcation of forest reserves in India as early as 1872,—twenty years before the setting aside of the first reserves in the United States, under President Harrison. He has since been active as Conservator of Forests in Cape Colony and British East Africa, and during the past year has been making a preliminary survey of the forests of New Zealand and preparing a report upon them.

With the beginning of the present year an amalgamation was effected between the Proceedings of the Society of American Foresters and the Forestry Quarterly, resulting in the appearance of the American Journal of Forestry. Dr. B. E. Fernow is Editor-in-Chief and Mr. Raphael Zon is Managing Editor, assisted by a group of seven associate editors representing different phases of forest work. The new journal will appear eight times a year, and will contain from 800 to 1200 pages of original articles, notes, reviews, personals, and reports of society affairs. The subscription price is $3 per annum.

Dr. W. C. Coker and Mr. H. R. Totten, of the University of North Carolina, have recently issued a booklet on The Trees of North Carolina. It contains untechnical descriptions of the 166 species of trees comprised in the flora of that state. A less conservative treatment would have included about a dozen more hawthorns, another dozen of shrubby forms which occasionally reach the size of small trees, and a few trees which have escaped from cultivation.

The University of Chicago Press announces the preparation of a volume entitled The Living Cycads, by Dr. C. J. Chamberlain, and another on Mechanics of Delayed Germination in Seeds, by Dr. William Crocker.

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The Plant World

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CONTAINING

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THE EFFECT OF SURFACE FILMS OF BORDEAUX MIXTURE ON THE FOLIAR TRANSPIRING POWER IN TOMATO PLANTS

JOHN W. SHIVE AND WILLIAM H. MARTIN

New Jersey Agricultural Experiment Station, New Brunswick, New Jersey

The use of Bordeaux mixture as a fungicide has given rise to many problems of physiological interest and importance. Frequent reports of increased and prolonged vitality in plants, and greater crop yields resulting from the use of this spray mixture, in the absence of all disease producing organisms, have aroused widespread interest and have led to many investigations in an effort to determine the nature of the influence of this fungicide upon healthy plants. During the past twenty years an extensive literature has accumulated dealing with questions of the influence of Bordeaux mixture upon various plant physiological processes, as well as upon plant structures. The results derived from the experimental work on the influence of this spray mixture on the rates of water loss by transpiration from sound plants, have led to conflicting opinions among investigators.

Studies of the influence of Bordeaux mixture on the rates of transpiration have been stimulated by the belief that prolonged vitality and greater yield from crop plants, such as the potato, following the use of this spray, are the result of a decrease in the rates of water loss, due to the presence of the spray material on the leaves. An explanation of this apparent conservation of the moisture in the leaves of the potato plant in dry seasons has been offered by Clinton,[1] upon the theoretical ground that the stomata and water pores of the leaves are clogged with the sediment of the spray, thus checking the loss of moisture by transpiration. The shading influence of Bordeaux mixture has

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[1] Clinton, G. P., Spraying potatoes in dry seasons. Conn. Agr. Exp. Sta. Report, 1909–10: 729–752.

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been considered in this connection by Schander,[2] who suggests that decreased rates of transpiration from plants sprayed with Bordeaux mixture are to be expected, since the spray material must exclude from the leaf certain rays which in the unsprayed leaf tend to accelerate the process of transpiration. An attempt to verify this theoretical conclusion by a study of leaf temperatures met with but little success.

As early as 1894, Frank and Krüger,[3] as the result of investigations in which they employed quantitative methods, reached the important conclusion that Bordeaux mixture, when applied to the leaves of plants as a spray, exerts an accelerating influence on the rates of water loss by transpiration. Very convincing evidence in support of these observations has recently been presented by Duggar and Cooley[4, 5] in two publications. These authors have demonstrated quantitatively that the normal rates of transpiration of abscised leaves of the castor bean (*Ricinus communis*, L.) are very materially increased by a surface film of Bordeaux mixture. With potted plants of the tomato (*Lycopersicum esculentum*, Mill.) and of the potato (*Solanum tuberosum* L.) they have shown also that as a result of an application of this spray mixture the transpiration rates were markedly increased in comparison with the rates from similar unsprayed plants. In a series of quantitative experiments which have just been published, Martin[6] has confirmed the work of Duggar and Cooley with abscised castor bean leaves and with potted tomato plants, and has extended his tests to include eight species of abscised leaves and five species of potted plants.

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[2] Schander, R., Ueber die physiologische Wirkung der Kupfervitriolkalkbrühe. Landw. Jahrb. **33**: 517–584. 1914.

[3] Frank, A. B. and Krüger, F., Ueber den direkten Einfluss der Kupfervitriolkalkbrühe auf die Kartoffelpflanze. Arb. d. deut. landw. Ges. 1894: 1–46.

[4] Duggar, B. M. and Cooley, J. S., The effect of surface films and dusts on the rate of transpiration. Ann. Missouri Bot. Gard. **1**: 1–22. 1914.

[5] ——— ———, The effect of surface films on the rate of transpiration: Experiments with potted potatoes. Ann. Missiouri Bot. Gard. **1**: 351–356. 1914.

[6] Martin, W. H., The influence of Bordeaux mixture on the rates of transpiration from abscised leaves and from potted plants. Jour. Agr. Res. **7**: 529–548. 1916.

Up to the present time, investigations dealing with the problem of the influence of surface films on rates of transpiration have been confined almost etirely to experiments with detached plant parts and with potted plants. Of the several methods available for the determination of the rate of water loss from plants or plant parts for any given set of conditions, the one most frequently employed by workers in this field is that of weighing the plants and their containers at stated intervals and determining the water loss in weight for each interval. The methods employed for the quantitative determination of water loss by transpiration can not be used with plants rooted in the soil under natural conditions. For such plants, therefore, absolute transpiration quantities cannot be determined.

The ability of plant leaves to give off moisture to their surroundings has been called their transpiring power.[7] This foliar characteristic can be measured directly through the power of the leaf surface to give off water to a standard water-absorbing surface. If the surrounding conditions remain the same and the degrees of the transpiring power vary from time to time, these variations must be due to internal conditions, and the various degrees of the transpiring power should be directly proportional to the rates of water loss. It has been pointed out that the quotient of the transpiration rate for a given time period divided by the evaporation rate from some standard evaporating surface for the same period, should be a measure of the effective internal conditions of the plant in question. The quotient here referred to has been called by Livingston[8] the relative transpiration ratio, and corresponds to the transpiring power, which may be measured by means of hygrometric methods.

Two such methods have been devised, by means of which the relative transpiring power of leaves may be measured. The two methods are the same in principle, but differ in the kind of materials composing the absorbing surfaces. The one employs the horn hygroscope of Darwin,[9] the other the hygrometric paper of Stahl.[10] It is the latter method as improved by Livingston and Shreve,[11] which has been employed in the present study.

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[7] Livingston, B. E., The resistance offered by leaves to transpirational water loss. Plant World 16: 1–36. 1913.

[8] Livingston, B. E., The relation of desert plants to soil moisture and to evaporation. Carnegie Inst. Wash. Publ. 50. Washington. 1906.

It was the purpose of the experiments here recorded to measure, at different hours of the day, by means of standardized cobalt chloride paper, the transpiring power of leaves which had previously been covered with a film of Bordeaux mixture, and to compare the values thus obtained with those derived from similar measurements made at the same hours upon untreated leaves of the same plant and of different plants. It was thought that such a comparison might give some indication of the relative rates of water loss from treated and untreated plants grown under agricultural conditions, a consideration of some importance in connection with the study of crop productions in general. The experiments further served as a practical field test of an improved method of cobalt chloride paper when applied to studies involving the effect of surface films on the loss of moisture from plant surfaces; studies which heretofore have been confined almost wholly to detached plant parts or to potted plants grown under artificial conditions.

It is a pleasure to acknowledge indebtedness to Dr. Byron D. Halsted for his kind consent to the use of a field plot on the experiment grounds of the Department of Botany of the New Jersey Agricultural Experiment Station, where the field tests were carried out.

METHODS

The method employed for the tests with cobalt chloride paper is essentially the one described by Livingston and recently improved by Livingston and Shreve, as already stated. The improved method makes use of composite paper slips consisting of a cobalt chloride paper slip and slips of two permanent color standards[12] firmly joined together into a composite slip which can be manipulated as a single piece. The permanent color standards are both blue, one being a little less intense in color than is thoroughly dry cobalt chloride paper, while the other is just faintly but perceptibly blue. By means of the composite slips, the two color standards and the cobalt chloride paper are brought to the leaf surface simultaneously. When the hygrometric paper is dry it has a slightly more intense blue color than the dark blue standard, but the color becomes less intense as moisture is absorbed. The test is begun when the color of the hygrometric paper just matches that of the more intensely colored standard. As the cobalt paper gradually becomes less intense in color, due to the absorption of water, a point is finally reached when its color just matches that of the pale blue standard. When this point is reached the test is considered ended. A test consists in determining the length of time elapsing between the occurrence of a fixed dark blue color and that of an equally fixed pale blue color. Since the two color standards are permanent, they furnish these two fixed points. In making a test, some error may, of course, occur from a failure to judge the exact time when the colors are correctly matched, either at the beginning or at the end of the test.

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[9] Darwin, F., Observations on stomata. Phil. Trans. Roy. Soc. Lond., B. **190**: 531–621. 1898.

[10] Stahl, E., Einige Versuche über Transpiration und Assimilation. Bot. Zeit. **52**: 117–146. 1894.

[11] Livingston, B. E. and Shreve, Edith B. Improvements in the method for determining the transpiring power of plant surfaces by hygrometric paper. Plant World **19**: 287–309. 1916.

In making the composite slips, the cobalt chloride paper and the two color standards were cut into 5 mm. squares. To join these together firmly very thin, black, water-proofed, gummed-cloth tape 2 cm. wide, was used. The tape was cut into 2 cm. squares. Two of these squares were placed together with the gummed face of the one against the cloth surface of the other, and the two were cemented together along one edge to prevent them from slipping out of place. Three circular holes, each 4 mm. in diameter were cut through this double tape square by means of a cork borer. The holes were so cut that each was about 1.5 mm. distant from the other two, thus forming a triangular arrangement. One layer of the double square was then folded back and over one of the openings was placed a slip of cobalt paper, over the second and third openings were placed slips of the dark blue and pale blue standards, respectively. After this the squares of tape were cemented together with the paper slips between, thus allowing each of the three paper surfaces to be exposed only through the circular openings in the tape. Each finished composite slip was permanently mounted (by means of the free gummed surface of the tape) upon a small cover glass cut to a suitable size (about 1.2 cm. by 1.5 cm.), and the margins of the slip were trimmed to the edges of the cover glass. Thus each composite slip was exposed to the leaf, always with the same surface, the observations being made through the cover glass. This feature of mounting the composite slips on cover glasses does not interfere with the standardization nor with the drying of the slip, and it reduces the possibility of the influence of the lateral leakage of moisture upon the time required for the color change of the cobalt chloride paper, when the slip is in contact with the leaf surface. Repeated tests with single mounted slips, over the standard water surface, showed less variation in the time required for the color change of the hygrometric paper than did similar tests with unmounted slips.

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[12] The permanent standard blue papers, as well as the cobalt chloride paper, were secured from The Plant World, Tucson, Arizona.

The Livingston method of applying the slips of hygrometric paper to the plant surface makes use of a spring wire clip, the movable ends of which are extended by two small glass plates which lie face to face when the clip is closed. The clip used in the present work differed from the usual form by having a small metal plate soldered to one of its free ends, the other free end resting against the face of the metal plate at right angles to its surface when the clip is closed. In making a test, the leaf is held between the metal plate and the mounted slip, the free end of the wire clip resting upon the cover glass of the slip and near its center. The pressure exerted by the spring of the clip is, therefore, imparted to the composite slip in such a way as to secure uniform contact between the slip and the leaf.

The composite slips were dried over an electric hot-plate and were then placed in small desiccators to retain them in the dry condition until used. The desiccators consisted of glass vials about 7.5 cm. long and about 2 cm. in diameter, fitted with paraffined cork stoppers. The desiccators were filled to about two-thirds of their capacity with anhydrous calcium chloride, which was covered with a thin layer of absorbent cotton held in place by a thin, perforated cork disc.

The composite hygrometric paper slips used for these tests were standardized once for all in the laboratory by the method employed by Trelease and Livingston,[13] and presented in detail by Livingston and Shreve. This method is based upon the assumption that the time required for the color change of the hygrometric paper over the standard evaporating surface is inversely proportional to the maximum vapor pressure of water, corresponding to the given temperature. Accordingly, if the time T required for the color change of a slip of hygrometric paper over the standard water surface at the known temperature t, is determined experimentally, it should be possible to calculate approximately the time for the same slip for any temperature t', the calculation being made by means of the following formula:

$$\frac{T_{t'}}{T_t} = \frac{P_t}{P_{t'}} \text{ or } T_{t'} = \frac{T_t \cdot P_t}{P_{t'}},$$

in which P_t represents the maximum vapor pressure of water for the temperature at which the actual laboratory test was made with the standard evaporating surface, and P_t' represents the vapor pressure corresponding to the temperature t'. The values of P_t and P_t' are obtained from published tables of aqueous vapor pressures. In making the calulations, it is understood, of course, as has been pointed out by Bakke,[14] that the only condition external to the hygrometric paper itself which can influence the time of color change over the standard water surface, is the temperature.

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[13] Trelease, S. F., and Livingston, B. E., The daily march of transpiring power as indicated by the porometer and by standardized hygrometric paper. Jour. Ecol. 4: 1–14. 1916.

[14] Bakke, A. L., Studies on the transpiring power of plants as indicated by the method of standardized hygrometric paper. Jour. Ecol. 2: 145–173 1914.

For each of the hygrometric paper slips here used, ten tests of the time response were made in the laboratory, all at approximately the same temperature. The air temperature in the immediate vicinity of the standard water surface and that of the standard water surface at the time when the tests were made, were here considered to be the same. The average time response for each slip, for the temperature at which the tests were made, was calculated, and the value thus obtained was used in the calculation of the time response of the slip in question (over the standard water surface) at field temperatures. In the standardization of the composite slips, all the precautions suggested by Livingston and Shreve were carefully observed, so that the calculations of the time response over the standard evaporating surface at field temperatures should be fully as satisfactory as actual field tests themsleves. It has been asserted by the last-named authors[15] that "it is practically certain that calculations for field temperatures, made from the average of a large number of tests in the laboratory, will prove to be more nearly correct than most single field tests, or even averages of a number of the latter."

The time required for the color change of the hygrometric paper from the dark blue to the light blue of the two color standards, upon the leaf surface, was determined by means of a stop watch. The time period in question will be designated by T_l, and the time period for the corresponding color change over the standard water surface will be termed T_e, following a similar usage of these symbols by Trelease and Livingston. The ratio of the calculated time period (T_e) required for the color change over the standard evaporating surface at field temperature, to the time period (T_l) required for the corresponding color change over the leaf at the same temperature, has been called by Livingston the index of transpiring power of the given leaf surface. This index, $\frac{T_e}{T_l}$, is a measure of the relative capacity of the leaf surface to give off-water vapor, in terms of the standard evaporating surface blanketed by one millimeter of air.

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[15] Livingston, B. E. and Shreve, Edith B., 1916, p. 303, *l. c.*

The determination of the indices of transpiring power in plants, by the method of standardized hygrometric paper, are made upon the supposition that the temperature of the leaf and that of the paper slip at the time when the tests are made, is the same as that of the surrounding air. A certain amount of error may here be introduced, as Trelease and Livingston have pointed out, since leaf temperature and air temperature at any given moment are seldom exactly the same. It is scarcely probable, however, that the difference in temperature between the leaf and the surrounding air is ever sufficient to render the results obtained from a series of tests very different from what they would be if the supposition were entirely true.

MEASUREMENTS AND RESULTS

As has already been stated, the tomato plants used for these tests were grown under agricultural conditions in the open field. The plants were about 80 cm. tall, profusely branched, and in full bloom when the tests were made. Two plants, growing side by side, with an intervening space of about one meter, were chosen for each days' experimentation. The leaves on about one-half the branches of one plant were sprayed on their upper and lower surfaces with Bordeaux mixture (4-4-50 formula of agricultural practice), care being taken to secure a complete covering with a fairly uniform film of the spray material. The leaves were sprayed on the day preceding that during which the tests were made. The leaves on the second plant remained unsprayed.

In selecting leaves to be tested, care was taken to choose only those of approximately the same age, on branches having about the same relative position on the stem. It has been pointed out by Bakke and by Bakke and Livingston[16] that leaves of different ages, and occupying different positions on the stem may differ markedly in their transpiring power, as this is measured by the method of standardized hygrometric paper. Preliminary tests, however, made with leaves chosen as indicated above, gave very uniform results.

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[16] Bakke, A. L. and Livingston, B. E., Further studies on foliar transpiring power in plants. Physiol. Res. 2: 51-71. 1916.

Nearly simultaneous tests with standardized hygrometric paper were made throughout the day upon three sets or groups of leaves: (1) upon sprayed leaves; (2) upon unsprayed leaves on the same plant as the sprayed leaves, and (3) upon leaves of the second unsprayed plant. For the sake of convenience in presenting the data, the three groups of leaves will be designated as series A, series B, and series C, in the order given. Three tests were made upon both the upper and lower foliar surfaces, of different but apparently similar leaves of each of the three groups. The observations, made at intervals of one hour, were begun early in the morning (5.00 a.m.) and were continued until sunset. Owing to a heavy dew on the morning of August 18, observations were not begun on this date until 9.00 a.m. Since the data for this day's tests are, therefore, not so extensive as those for August 10 and for August 14, they are given in full in table 1, where the hours are numbered consecutively in the day. The tests were made, of course, within the stated hour, usually within the first twenty or thirty minutes of that hour, for the lower leaf surfaces. A somewhat longer period of time was required for the tests on the upper leaf surfaces where the stomata are less numerous than on the lower surfaces; the number of stomata per square millimeter on the upper and lower surfaces of the leaves of tomato plants being estimated by Duggar[17] to be 12 and 130, respectively. The temperatures given were read, at the beginning of the hour indicated, from thermometers suspended among the leaves of the plants. In table 1 are given, for each hour indicated, the three individual time coefficients and the corresponding individual indices of transpiring power, for upper and for lower leaf surfaces, for each series, as are also the averages of these. The last line of each horizontal section of the table presents, in full-face type, the indices of transpiring power for the entire leaf surfaces, these being derived by taking the mean of the average indices for the upper and lower foliar surfaces. These are followed on the same line in the last two columns of the table, by the ratios of the indices for the entire leaf surfaces of series A to the corresponding indices of each of the other two series.

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[17] Duggar, B. M., Plant Physiology. New York. 1915.

It will be observed from the last two columns of table 1 that the ratios of the index values for entire leaf surfaces of the sprayed leaves (series A) to the corresponding values of each of the other two series (series B and series C), while by no means constant, show comparatively small differences. The average indices of the relative transpiring power of the sprayed leaves (series A) may, therefore, be considered roughly proportional to the corresponding indices of each of the other two series (series B and series C). The average of the values of the first of the two sets of ratios here considered is 1.21, and of the other it is 1.18, as given at the end of the last two columns of table 1. The indices of transpiring power of the sprayed leaves average, therefore, 21 per cent. higher than the corresponding indices of the unsprayed leaves of the same plant, and 18 per cent. higher than the corresponding indices of the leaves of the unsprayed plant, for the day during which the tests were made (August 18).

The average numerical data for the tests made on August 10 and on August 14 are brought together in table 2, where the individual time coefficients for the two leaf surfaces and the corresponding individual indices are omitted. On August 10, readings were taken on the upper and lower foliar surfaces of the leaves of a sprayed plant and of an unsprayed plant, only. Series B, therefore, does not appear in the table for this date. Each index of transpiring power for both upper and lower leaf surfaces, as given in table 2, represents the average value of three individual indices, and was obtained in precisely the same manner as were the average indices in table 1. The ratios presented in the last two columns of the table correspond to those which appear in the last two columns of table 1.

The ratios given in the last two columns of table 2 are quite as uniform in value as are the corresponding ratios in table 1.

TABLE 1

Date of relative transpiring power (by standardized cobalt chloride paper) for upper, lower, and for entire foliar surfaces, of leaves of tomato plants. Series A, sprayed leaves; series B, unsprayed leaves of the same plant as the sprayed leaves; series C, leaves of an unsprayed plant. August 18, 1916.

HOUR OF OBSERVATION	OBSERVED TEMPERATURE (°C.)	CALCULATED TIME FOR COLOR CHANGE OVER STANDARD WATER SURFACE	OBSERVED TIME FOR COLOR CHANGE ON LEAF (SEC.)			INDEX OF TRANSPIRING POWER			RATIO OF INDICES FOR ENTIRE FOLIAR SURFACES, SPRAYED TO UNSPRAYED LEAVES	
			Series A	Series B	Series C	Series A	Series B	Series C	$\frac{A}{B}$	$\frac{A}{C}$
9	26.0	34.6	U* 440	474	460	0.079	0.073	0.075		
			U 442	666	485	0.078	0.053	0.071		
			U 438	600	490	0.079	0.058	0.071		
						Av. 0.079	0.061	0.072		
			L* 61	72	100	0.567	0.481	0.346		
			L 74	91	114	0.468	0.380	0.303		
			L 92	106	84	0.376	0.326	0.412		
						Av. 0.470	0.396	0.354		
						E* **0.275**	**0.229**	**0.213**	1.20	1.29
10	26.5	33.7	U 340	570	430	0.099	0.059	0.078		
			U 350	510	390	0.096	0.066	0.086		
			U 420	550	570	0.081	0.061	0.059		
						Av. 0.092	0.062	0.075		
			L 80	61	87	0.422	0.552	0.388		
			L 61	95	105	0.554	0.355	0.321		
			L 71	62	89	0.475	0.544	0.378		
						Av. 0.483	0.483	0.362		
						E **0.287**	**0.272**	**0.218**	1.06	1.32
11	27.0	32.7	U 315	360	373	0.104	0.096	0.088		
			U 380	390	390	0.086	0.084	0.084		
			U 320	—	465	0.102	—	0.070		
						Av. 0.097	0.088	0.081		
			L 63	87	99	0.520	0.376	0.331		
			L 75	72	90	0.436	0.455	0.364		
			L 77	85	77	0.425	0.385	0.425		
						Av. 0.460	0.405	0.376		
						E **0.279**	**0.247**	**0.229**	1.13	1.22
12	29.0	29.1	U 210	380	310	0.138	0.078	0.094		
			U 240	—	326	0.121	—	0.089		
			U 240	—	—	0.121	—	—		
						Av. 0.126	0.078	0.092		
			L 53	59	60	0.550	0.494	0.485		
			L 50	54	64	0.580	0.540	0.455		
			L 44	49	53	0.662	0.595	0.550		
						Av. 0.598	0.485	0.573		
						E **0.362**	**0.282**	**0.328**	1.28	1.10

TABLE 1—*Continued*

HOUR OF OBSERVATION	OBSERVED TEMPERATURE (°C.)	CALCULATED TIME FOR COLOR CHANGE OVER STANDARD WATER SURFACE	OBSERVED TIME FOR COLOR CHANGE ON LEAF (SEC.)			INDEX OF TRANSPIRING POWER			RATIO OF INDICES FOR ENTIRE FOLIAR SURFACES, SPRAYED TO UNSPRAYED LEAVES	
			Series A	Series B	Series C	Series A	Series B	Series C	A/B	A/C
13	28.5	29.9	U 325	580	378	0.092	0.052	0.079		
			U 376	540	410	0.084	0.056	0.073		
			U 405	519	545	0.074	0.058	0.055		
						Av. 0.083	0.055	0.069		
			L 57	78	82	0.507	0.383	0.365		
			L 59	67	78	0.490	0.447	0.383		
			L 68	91	88	0.425	0.328	0.340		
						Av. 0.478	0.386	0.363		
						E **0.280**	**0.220**	**0.216**	1.27	1.29
14	29.0	29.1	U 425	790	670	0.071	0.038	0.045		
			U 310	510	595	0.097	0.059	0.050		
			U 424	550	628	0.071	0.055	0.043		
						Av. 0.080	0.050	0.046		
			L 63	82	84	0.462	0.356	0.347		
			L 66	74	71	0.441	0.394	0.411		
			L 81	73	77	0.360	0.399	0.378		
						Av. 0.421	0.383	0.412		
						E **0.250**	**0.216**	**0.229**	1.16	1.09
15	28.5	29.9	U 560	770	710	0.053	0.039	0.042		
			U 600	756	810	0.050	0.040	0.037		
			U 550	730	740	0.055	0.041	0.040		
						Av. 0.052	0.040	0.039		
			L 87	104	83	0.344	0.288	0.360		
			L 74	86	92	0.404	0.348	0.325		
			L 82	102	101	0.365	0.293	0.296		
						Av. 0.371	0.310	0.327		
						E **0.212**	**0.175**	**0.188**	1.21	1.13
16	27.5	31.7	U 687	660	1030	0.046	0.048	0.032		
			U 660	716	812	0.048	0.044	0.039		
			U 660	880	865	0.048	0.036	0.042		
						Av. 0.047	0.042	0.035		
			L 149	225	167	0.211	0.140	0.189		
			L 165	230	150	0.191	0.137	0.250		
			L 140	300	180	0.225	0.105	0.175		
						Av. 0.209	0.128	0.205		
						E **0.128**	**0.085**	**0.122**	1.51	1.05

TABLE 1—*Continued*

HOUR OF OBSERVATION	OBSERVED TEMPERATURE (°C.)	CALCULATED TIME FOR COLOR CHANGE OVER STANDARD WATER SURFACE	OBSERVED TIME FOR COLOR CHANGE ON LEAF (SEC.)			INDEX OF TRANSPIRING POWER			RATIO OF INDICES FOR ENTIRE FOLIAR SURFACES, SPRAYED TO UNSPRAYED LEAVES	
			Series A	Series B	Series C	Series A	Series B	Series C	A/B	A/C
17	25.0	34.7	U 650	1245	1380	0.052	0.030	0.028		
			U 655	900	1270	0.051	0.042	0.031		
			U 840	1185	1080	0.044	0.032	0.037		
						Av. 0.049	0.034	0.032		
			L 260	254	220	0.133	0.137	0.158		
			L 225	320	295	0.154	0.108	0.117		
			L 300	338	250	0.116	0.103	0.138		
						Av. 0.134	0.116	0.134		
						E **0.091**	**0.075**	**0.083**	1.21	1.10
18	23.5	36.8	U 960	1330	1270	0.038	0.028	0.029		
			U 1080	1390	1440	0.034	0.027	0.026		
			U 1200	1275	1430	0.031	0.029	0.026		
						Av. 0.034	0.028	0.027		
			L 260	290	400	0.141	0.127	0.094		
			L 285	420	360	0.129	0.087	0.104		
			L 330	250	350	0.111	0.147	0.107		
						Av. 0.127	0.120	0.102		
						E **0.080**	**0.074**	**0.065**	1.08	1.23
								Av.	1.21	1.18

* The letters U, L, and E here denote upper surface, lower surface, and entire surface, respectively.

The low value indicated in the last column of the table for the seventh hour, August 14, is not explained. The average value of the ratios of indices for entire leaf surfaces of the sprayed leaves (series A), to the corresponding indices for the leaves of the unsprayed plant (series C), for August 10, is 1.25. The indices of transpiring power for the sprayed leaves average, therefore, 25% higher on this day than the corresponding indices for the leaves of the unsprayed plant. The average ratio value of the indices of the sprayed leaves (series A) to those of the unsprayed leaves on the same plant (series B), for August 14, is 1.23. The corresponding average ratio value of the sprayed leaves to the leaves of the unsprayed plant for the

TABLE 2

Average data of relative transpiring power (by standardized hygrometric paper) for upper, lower, and for entire foliar surfaces, of leaves of tomato plants. Series A, sprayed leaves; series B, unsprayed leaves of the same plant as the sprayed leaves; series C, leaves of an unsprayed plant

	HOUR OF OBSERVATION	INDEX OF TRANSPIRING POWER OF FOLIAR SURFACES									RATIO OF AVERAGE INDICES FOR ENTIRE FOLIAR SURFACES, SPRAYED TO UNSPRAYED LEAVES	
		Series A			Series B			Series C				
		U*	L*	E*	U	L	E	U	L	E	A/B	A/C
August 10	5	0.078	0.188	0.133	—	—	—	0.051	0.161	0.106	—	1.25
	6	0.123	0.129	0.171	—	—	—	0.077	0.199	0.138	—	1.24
	7	0.092	0.363	0.228	—	—	—	0.077	0.321	0.199	—	1.15
	8	0.112	0.545	0.329	—	—	—	0.071	0.443	0.257	—	1.28
	9	0.268	0.659	0.463	—	—	—	0.135	0.642	0.388	—	1.19
	10	0.287	0.790	0.538	—	—	—	0.205	0.598	0.401	—	1.34
	11	0.287	0.851	0.569	—	—	—	0.185	0.642	0.414	—	1.37
	12	0.220	0.922	0.571	—	—	—	0.164	0.723	0.443	—	1.29
	13	0.154	1.022	0.587	—	—	—	0.132	0.942	0.537	—	1.09
	14	0.130	0.741	0.435	—	—	—	0.117	0.641	0.379	—	1.15
	15	0.177	0.642	0.409	—	—	—	0.116	0.438	0.277	—	1.47
	16	0.111	0.539	0.325	—	—	—	0.105	0.381	0.243	—	1.34
	17	0.098	0.323	0.210	—	—	—	0.089	0.248	0.168	—	1.25
	18	0.078	0.176	0.124	—	—	—	0.067	0.163	0.115	—	1.08
											Av.	1.25
August 14	5	0.038	0.198	0.118	—	0.160	—	0.046	0.173	0.110	—	1.07
	6	0.072	0.219	0.146	0.046	0.228	0.137	0.051	0.201	0.121	1.07	1.21
	7	0.073	0.178	0.126	0.037	0.171	0.104	0.064	0.198	0.131	1.21	0.97
	8	0.094	0.192	0.143	0.043	0.191	0.117	0.075	0.193	0.134	1.22	1.07
	9	0.087	0.292	0.190	0.048	0.307	0.178	0.038	0.225	0.132	1.07	1.44
	10	0.107	0.378	0.234	0.045	0.325	0.185	0.086	0.346	0.216	1.26	1.08
	11	0.096	0.573	0.340	0.044	0.476	0.260	0.060	0.397	0.227	1.31	1.49
	12	0.089	0.448	0.267	0.043	0.385	0.214	0.058	0.340	0.199	1.25	1.34
	13	0.098	0.321	0.210	0.063	0.311	0.187	0.076	0.285	0.181	1.12	1.16
	14	0.069	0.253	0.161	0.048	0.250	0.144	0.044	0.191	0.118	1.12	1.36
	15	0.059	0.236	0.148	0.037	0.212	0.125	0.033	0.206	0.120	1.18	1.23
	16	0.055	0.227	0.141	0.045	0.151	0.098	0.036	0.161	0.099	1.44	1.43
	17	0.040	0.208	0.124	0.032	0.137	0.085	0.037	0.190	0.114	1.46	1.09
	18	0.043	0.124	0.084	0.032	0.099	0.066	0.033	0.122	0.078	1.27	1.08
											Av. 1.23	1.29

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* The letters U, L, and E, here denote upper surface, lower surface, and entire surface, respectively.

same day is 1.29. This indicates that the indices of transpiring power for the sprayed leaves average 23% higher than for the unsprayed leaves of the same plant (series B), and 29% higher than for the leaves of the unsprayed plant (series C). A comparison, similar to the one made here, of the ratio values derived from the data of August 18, considered in connection with table 1, shows that the indices of transpiring power for the sprayed leaves average 21% and 18% higher than the corresponding indices for the unsprayed leaves of the same plant (series B) and for the leaves of the unsprayed plant (series C), respectively.

It is interesting to note in this connection the results obtained by Duggar and Cooley[18] with potted tomato plants. In an experiment extending over a time period of more than three weeks, during which quantitative measurements of transpiration were made, these authors found the water loss per gram of green substance from ten plants sprayed with strong Bordeaux mixture (4–6–50 formula of agricultural practice) and from ten similar plants sprayed with weak Bordeaux mixture (2–3–50 formula) to be 25% and 13% higher, respectively, than the corresponding water loss from ten similar unsprayed plants. In a similar experiment extending over a time period of sixteen days, Martin[19] found the water loss per gram green substance and per gram dry substance from six potted tomato plants sprayed with Bordeaux mixture (4–4–50 formula) to be 7% and 9% higher, respectively, than the corresponding water loss from six similar unsprayed plants. While the results noted are not strictly comparable with those here obtained by means of the method of standardized hygrometric paper, it appears that such a method as the one here employed with plants under cultivation, may be expected to yield results which are in entire accord with those obtained by means of the quantitative methods usually employed.

The three separate series of hourly index values for entire foliar surfaces, given in tables 1 and 2, are represented graphically in figure 1. Here the abscissas indicate the hours (numbered consecutively in the day) at which the tests were made, and the ordinates represent the index values for entire leaf surfaces. The heavy black line indicates the march of the transpiring power of the sprayed leaves, the narrow unbroken line and the broken line represent the march of corresponding indices for the

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[18] Duggar, B. M. and Cooley, J. S., 1914, p. 19, *l. c.*

[19] Martin, W. H., 1916, p. 546, *l. c.*

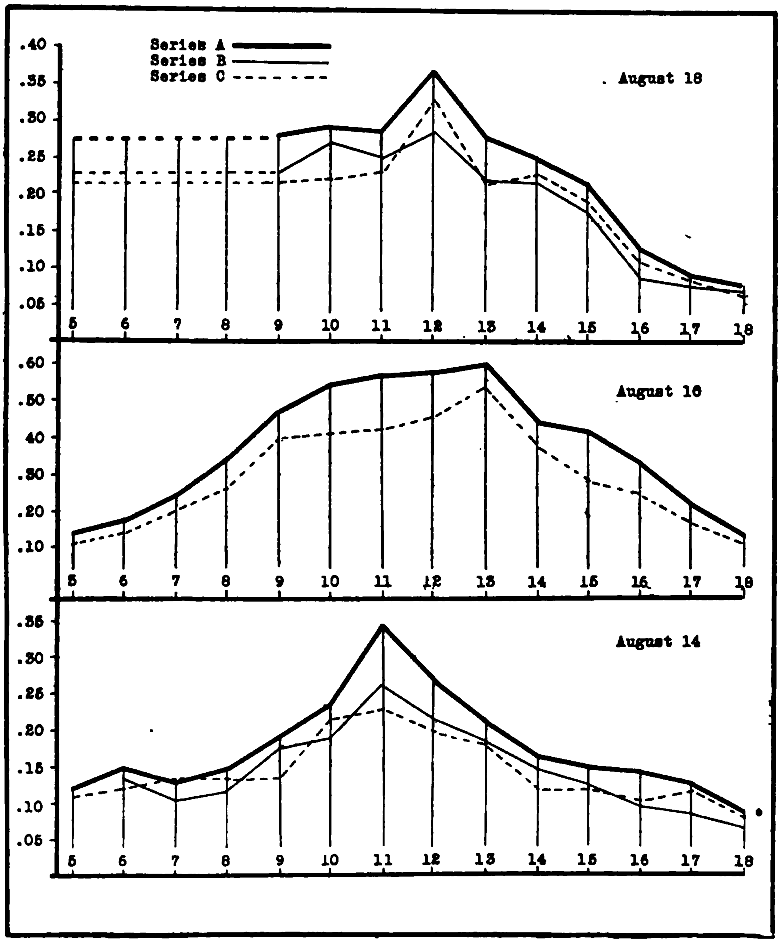

Fig. 1. Graphs showing the march of average foliar transpiring power of sprayed and unsprayed leaves of tomato plants, from hour 5 to hour 18, of August 10 and 14, and from hour 9 to hour 18, of August 18. Series A, sprayed leaves; series B, unsprayed leaves on the same plant as the sprayed leaves; series C, leaves of an unsprayed plant.

unsprayed leaves of the same plant (series B) and for the leaves of the unsprayed plant (series C), respectively.

Inspection of the graphs shows that the index values for the sprayed leaves are, with only one exception, greater than are the corresponding values for the unsprayed leaves, whether on the same plant or on a different plant. The single exception, to which reference has already been made, is given for the seventh hour, August 14. Here the index value for the leaves of the unsprayed plant (series C) is slightly higher than the corresponding value for the sprayed leaves.

The various graphs show slight irregularities, but there is a marked tendency for the same irregularities to occur at corresponding points on the three graphs (two for August 10) of a set. This is particularly striking for the graphs representing the indices for the sprayed and unsprayed leaves of the same plant. The three sets of graphs show clearly that the foliar transpiring power, as measured by the method of standardized hygrometric paper, rises to its maximum about the middle of the day, falls somewhat abruptly for several hours, and then more slowly to the low values attained late in the day. It will be observed that the maximum index values for the three sets of graphs are here indicated at different hours of the day, but the maximum for each graph of a single set appears at the same hour. The maximum transpiring power of the leaves of each series on August 10 was attained at the thirteenth hour. The maxima for August 14 and for August 18 were reached at the eleventh hour and the twelfth hour, respectively.

It is to be noted that the indices for entire leaf surfaces of series A and series C, on August 10, are, with only one exception, much higher in value than are the corresponding indices on either of the other two days. This striking difference in the values of corresponding indices is not at once made apparent from a casual inspection of the graphs, since the graphs of indices for August 10 are plotted on a different scale than are those for the other two days. The difference here indicated may be due to the fact that for several days preceding August 10, a rainy season prevailed, so that the moisture content of the soil in which the plants were rooted was very much greater on this day than was the case on either of the other two days.

The graphs here presented possess all the characteristics of the typical graphs of foliar transpiring power thus far published, and in addition to this, they bring out very clearly the influence of a surface film of Bordeaux mixture upon the transpiring power of the leaves of the tomato plants here employed, for the particular sets of conditions under which the tests were made. Whatever may be the nature of the influence of a film of Bordeaux mixture, effective in producing higher indices of transpiring power, it is clear that this influence is just as effective to increase and to maintain these indices when their values are low as it is when their values are high.

It should be stated that the data here presented involve the tests of comparatively few of the total number of leaves of a single plant. As has already been pointed out, the leaves chosen from each plant for these tests were neither very old nor very young, and may, therefore, be considered to be representative of the leaves of the plant as a whole. Had it been practicable to make simultaneous tests, similar to these, upon a large number of leaves at various stages of growth and maturity, or upon all the leaves of each plant here employed, it is questionable whether the average data thus obtained would show the results to be essentially different from those here presented.

It was not the purpose here to inquire into the causes underlying the modification of the indices of transpiring power through the agency of Bordeaux mixture, but merely to determine the effect of surface films of this spray material on the transpiring power of tomato plants under cultivation in the open field, by the improved method of standardized hygrometric paper.

SUMMARY

The results obtained from these tests demonstrate clearly enough that the method here employed furnishes an adequate and simple means of studying the transpiring power of plants which have been treated with surface films of Bordeaux mixture, and it is here suggested that the method is equally applicable to similar studies involving the use of other spray materials. The method may also be found useful for the investigation of the transpiring power of diseased plants, or of diseased plant parts: a matter of considerable importance in connection with certain pathological, as well as physiological studies.

For each single day, the average values of the indices of transpiring power of the leaves treated with films of Bordeaux mixture may be considered to be roughly proportional to the corresponding values of the untreated leaves of the same and of different plants.

The indices of transpiring power of the treated leaves, for August 14 and 18, show values averaging 23% and 21% higher, respectively, than the corresponding index values of the untreated leaves of the same plant. In like manner, the index values of the treated leaves, for August 10, 14, and 18, average 25%, 29%, and 18%, higher, respectively, than do the corresponding indices of the leaves of the untreated plants.

The graphs showing the march of foliar transpiring power, indicate that the maximum indices occur near the middle of the day. The graphs of each single set, representing the index values of the three groups of leaves here considered, all agree in indicating their maxima at the same hour of the day, although the maxima of the three different sets of graphs occur at different hours on different days.

The influence of Bordeaux mixture effective in producing higher indices of transpiring power, of the plants here employed, under the particular sets of conditions prevailing when the tests were made, is just as effective when these indices are low as it is when they are high.

SEEDING HABITS OF SPRUCE AS A FACTOR IN THE COMPETITION OF SPRUCE WITH ITS ASSOCIATES

LOUIS S. MURPHY

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I wish to make it entirely clear at the outset that my contribution to this discussion is chiefly by way of suggestion, and that the observations on which my paper is based were hardly sufficient to justify too positive a conclusion. Yet, I take it that you are not averse to having brought to your attention preliminary findings which point the way to promising new fields of research.

Doubtless many, if not all, of you are familiar with the fact that red spruce (*Picea rubens*) bears a full crop of seed only at infrequent intervals, which vary from four to seven years. This in itself is a considerable handicap, and is indeed generally so accepted in accounting for the paucity of spruce reproduction as compared with that of balsam fir and the hardwoods with which it is associated, most of which are annual seeders. Other causes commonly assigned to this failure of spruce to maintain itself in the young growth with species with which it is able to compete so successfully in later life are its exacting demands on seed bed as to moisture, texture, and acidity of the soil, and its extremely slow growth in early life even under most favorable circumstances.

Still another factor, however, the early dispersal and germination of spruce seed, may also be concerned. It is this factor hitherto apparently unnoticed which I wish to present for your consideration. My observations on this point were made in the fall of 1910 and the spring of 1911 when I was engaged in a study of the growth and development of spruce stands, particularly "second growth," or "old pasture," stands. It so happened that 1910 was also a full seed year for spruce in the northern New Hampshire and adjoining Maine regions and weather conditions favored early maturity and dispersal of the seed.

During the latter half of September an examination of the forest floor under the normal cover of even-aged spruce stands revealed a large quantity of germinated spruce seed which must have been from the recently ripened seed crop, since only the seed leaves were developed, and in many cases even the seedcoat still enveloped the tips of the embryonic leaves. These spruce germinates were so thick in places as to make it impossible to place a finger on the ground without crushing several. Balsam fir seedlings were also found with them, but these were remotely scattered as single individuals and were almost without exception spring germinates with well developed stems and permanent leaves. One and two year old balsam seedlings were also present. Spruce of this age was entirely lacking and seedlings of the previous spring's germination were also only sparingly represented.

Balsam seed trees were not very numerous, so that this condition did not of itself indicate much with relation to the behavior of that species, but subsequently a stand of almost pure balsam within a short distance of the spruce plot just mentioned was examined. Here, although the site was not quite the same, the density of the cover was very similar, and in places conditions were more favorable to germination and early growth than in the spruce stand. A close examination of the humus and light moss cover failed to disclose more than a scattering of balsam fall germinates, although the presence of new sound seeds in considerable quantity was observed. Balsam seedlings from spring germinates were plentiful, occurring as individuals, while one and two year old seedlings were also numerous.

In contrast to this condition spruce in the young growth of open pastures was observed to be much more prevalent than balsam. In explanation of this apparent reversal of the reproductive capacities of the two species it seems entirely probable that in the fall soil moisture and general climatic conditions are, in the open, much less favorable to germination of spruce than in the forest. Furthermore, the principal seed distribution of spruce in the open, except in the immediate vicinity of seed trees, doubtless occurs later in the season from seeds subsequently dislodged from the cones by the winter storms. Thus in the open a relatively larger percentage of spruce seeds would lie over for spring germination than in the forest with a correspondingly better chance of becoming permanently established

As to the less favorable showing of balsam in the open, this was unquestionably due in part to the smaller production of balsam seed, since there were fewer balsam than spruce seed trees in the particular locality where conditions were observed. Then too, balsam seeds are heavier than spruce, so that they would not be carried so far by the wind, and balsam seedlings are also browsed by cattle much more than spruce.

If this behavior of spruce and of balsam in regard to time of seed disbursal and germination is typical of the two species, it can be readily seen that even with a smaller proportion of fertile seed than spruce, balsam would have a considerable advantage. The fall germination of spruce would subject the very young seedlings to a material reduction in numbers and vitality during the first winter as a result of winter killing, while the loss to balsam from this cause would be comparatively insignificant.

Concerning spruce competition with hardwoods, observation made in Waterville, New Hampshire, the following spring (1911), in connection with the five year remeasurements of sample plots of spruce reproduction under hardwoods, showed a considerable number of spruce germinates under the hardwood leaf litter shed the previous fall. Many of these, however, were either wilted or had already succumbed to "damping-off." Others were bleached almost white, and the stem and leaves were turgid and succulent, but without vigor, doubtless from too humid growing conditions and lack of sufficient light. This was particularly noticeable under moosewood and young hardwood brush with large coarse foliage. The absence of any one-year or two-year spruce on these plots was also noticeable. A marked contrast to this condition was found where any part of these plots happened to be protected from the heavy hardwood leaf fall by a group of suppressed spruce, or small balsams, or a pile of slash. Here there would be a generous number of spruce germinates and one and two-year seedlings as well. In fact, reproduction appeared to be entirely satisfactory.

Here again the early seed dispersal habit of spruce very probably works to the disadvantage of its reproduction. Whether fall germination takes place in these circumstances or not the seeds, or germinates, will be covered with a thick layer of hardwood leaves. In the spring the warm rains and sun start fermentation of the mulch, and while this at first affords conditions exceedingly favorable to the germination of the spruce seed, the young seedlings are unable to survive the continued heat and humidity and the general smothering effect of the hardwood leaf litter. The trouble thus seems to be not that the seedlings are unable to get their roots into mineral soil or other suitable material as is usually claimed but that the heavy mulch prevents them from getting their shoots up into the needed light and air.

BOOKS AND CURRENT LITERATURE

Pine-Barrens of New Jersey.—Probably no region in North America is more famous from a botanical standpoint than the New Jersey Pine-Barrens. Situated as it is at the very threshold of New York and Philadelphia, this barren wilderness of pines, so strikingly different from the deciduous forest areas to the west both in the general aspect of its vegetation and in the unique nature of its flora, has been a happy hunting-ground for local collectors since the earliest days of botanical study in America. Several local floras, dealing with portions or all of the area, have been published at various times, and the most recent of these, by Witmer Stone,[1] leaves little to be desired along floristic lines. Stone was perhaps the first writer to clearly outline the boundaries of the pine-barrens, as delimited from other parts of the New Jersey coastal plain. It has remained for Harshberger to discuss their vegetation from the ecological point of view.[2]

The subject matter in the present work can be grouped for the most part under one of three heads: (1) Origin and present distribution of the pine-barrens; (2) Ecology of the vegetation as a whole (synecology); (3) Ecology of individual plants (autecology). In attempting to explain the origin of the pine-barrens Harshberger urges the very reasonable theory, which he himself first suggested[3] but which later was worked out in detail by Taylor,[4] that the vegetation of this area represents an isolated relict of an ancient Miocene coastal plain flora, the present distribution of which is practically coextensive with the Beacon Hill (geological) formation of New Jersey and whose perpetuation may be attributed to the fact that the area which it occupies, in contrast to surrounding portions of the coastal plain, has been uninterruptedly out of the water since upper Miocene times. That the ecologically more advanced deciduous types of forest which prevail in regions farther west have been unable to displace the relatively primitive type found here is thought by Harshberger, on the basis of his studies of the soils of the region (chapter 4) and of the distribution of the subterranean organs of pine-barren plants (chapters 16 and 17), to be due largely to the fact that the dominant plants are superfically rooted perennials, whose roots and root-stocks are so intricately matted and interlaced, and whose reciprocal relations are so intimate that "no alien plant has a chance of establishing itself in an area where the original vegetal covering has remained unbroken."

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[1] Stone, Witmer, Ann. Rep. N. J. State Mus., pp. 22–828, pls. 1–129 + map. Trenton, 1911.

[2] Harshberger, J. W., The Vegetation of the New Jersey Pine-Barrens, pp. 1–329, figs. 1–284 + map. Christopher Sower Company, Philadelphia, 1916 ($5.00).

[3] Harshberger, J. W., Phytogeographic Survey of North America, pp. 219–221. Leipzig, 1911.

[4] Taylor, Norman, Torreya **12**: 229–242, 1912.

Nine types of natural plant formations (*sic*) are distinguished: the pine-barren, cedar swamp, deciduous swamp, savanna, marsh, pond, river bank, bog, and plains formations. In addition to these there are four successional plant formations (*sic*): the cranberry bog, scrub oak, oak coppice, and mixed pine-oak formations. These latter arise secondarily, due to the disturbing of the primary associations. The natural formations are discussed in detail, but only the more prominent of these need be mentioned further here. The Pine-Barren Formation, which occupies most of the territory outside of the swamps, comprises a fairly open stand of (mainly) *Pinus rigida*, associated with which, and forming five or six more or less definite strata of vegetation, are various smaller trees, especially *Quercus marilandica* and other species of oak, shrubs and herbs. Three distinct facies of the pine-barren formation are distinguished: high pine-barren, flat pine-barren and low or wet pine-barren, all of which are treated in some detail. The Plains Formation occupies an elevated tract of country about twenty-five square miles in area, its vegetation consisting of a scrubby forest of *Pinus rigida* and *Quercus marilandica* only a few feet high. Because of the abundance here of *Corema Conradii*, elsewhere absent, this formation is designated the Coremal. The causes of the development of this peculiar type of forest have been variously explained. Harshberger advances the view, based on an extensive series of cultural experiments with the soils of the area, that the character of the vegetation is in large part correlated with the presence of a stiff, impervious subsoil or hard-pan, similar to the *Ortstein* of the Germans. In connection with the description of the pine-barren and plains vegetation, attention is called to parallel formations in Long Island, Nantucket, and Germany. The Savanna Formation presents one of the most unique types of the region. It embraces flat, grassy tracts which occupy low stream terraces and may be miles in extent. In wet savannas, which are more or less arbitrarily separated from swamps, the dominant vegetation consists of grasses and sedges, and trees may be practically absent. Dry savannas differ in aspect from wet savannas primarily in the presence of scattered trees or clumps of trees (mostly *Pinus rigida*). It is in these savannas that *Tofieldia*, *Abama*, and several other distinctive pine-barren plants are found. The Cedar Swamp Formation represents the common swamp type. Such swamps are extensively developed in shallow depressions and low grounds along the sluggish streams of the region. The character tree is *Chamaecyparis thyoides*. Due to lumbering operations and other causes many former cedar swamps have been superseded by deciduous swamps, but it should be noted that many of the latter are apparently natural. The distribution of the pine-barren, plain, savanna, and cedar swamp formations is indicated in colors on the large map which accompanies the volume.

The last half of the book is largely devoted to matters of autecological interest. Among other things, there is a chapter (15) on the phytophenology of the pine-barren vegetation, in which the flowering or fruiting periods of practically all the pine-barren species are presented in tabular form; a chapter (16) on vegetative propagation and the gross structure of the shoot and root in typical pine-barren species, illustrated by nearly fifty line drawings; a chapter (18) on leaf-forms of pine-barren plants, and another (19) on the microscopic leaf structure of more than fifty species, all of which are figured in cross-section; a chapter (20) on cone and seed production of the pitch pine, and viviparity in *Quercus marilandica*; and finally a chapter (22) on pine-barren plants from an evolutionary standpoint. Altogether the book probably represents the most comprehensive treatment of a relatively small area from an ecological viewpoint that has ever been attempted in this country.—George E. Nichols.

Recent Text-books.—Two new text-books of botany have recently come out which make very distinct appeals for recognition—the one[1] by a college teacher of long experience and acknowledged success, the other[2] by the efficient director of a botanical garden the main purpose of which is to teach. In covers and contents the books are surprisingly different from each other. The four hundred pages of Ganong's book are bound in stiff boards, are abundantly illustrated from nature, the authorities, and the diagrammers, and present a scholarly and therefore conservative statement of the main facts of botanical science today. The six hundred and forty pages of Gager's book, which would occupy no more space than Ganong's if trimmed to the same size, are bound in flexible covers, are equally illustrated but from sources not so immediately recognized, and not only present the facts but reflect the fashions in botanical science today. Both are designed to interest the student who has no intention of becoming a botanist (unless perchance he may become that best of applied botanists—a farmer), furnishing him with palatable information and giving him such mental discipline as may help him as an "educated" citizen to think a little more clearly and to conclude a little more correctly.

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[1] Ganong, W. F., A Text-book of Botany for Colleges. New York, The Macmillan Company, 1916 ($2.00).

[2] Gager, C. Stuart, The Fundamentals of Botany. Philadelphia, P. Blakiston's Son and Company, 1916 ($1.50).

In Gager's book one meets a distinct novelty in the small portraits of the most eminent contributors to the science of botany. To the advanced student, the faces of Ingen-Housz, Priestly, and others, have a very human interest, and to many other students this human interest may also appeal. The faces are of men whom one would gladly have known; they make the famous names more real. But does the casual student care enough to justify the cost of space? Probably not, but also it is not the casual student of whom much can be made by any means whatsoever; and the reviewer is not sure that the botanical facts which might have filled the space of these figures would make any more desirable impression.

In Ganong's book one finds the usual botany expounded most unusually well. In Gager's the newer and more immediate relations of plant life and plant study to human life find more direct and thorough treatment. Botany as an intellectual pursuit, as a source of interest and satisfaction, has long been recognized: but botany as a vital, practical interest is comparatively new. The intimate relation of the study of plants to the economic condition of mankind is not generally acknowledged, if generally recognized at all. When the world of men realizes—not merely vaguely knows—that all its food is produced by plants, that most of its conveniences and comforts come from plants, and that its health is dependent upon plants, it will turn to a much more intense and much broader study of plants, their workings, and their conditions of work, than is now the case. Books which emphasize these relations to readers whom they have interested have a new and valuable reason for existence. These two are such books and are correspondingly commendable; they are excellent text-books, human, intelligent, and informing.—George J. Peirce.

NOTES AND COMMENT

It frequently happens that the published results of zoological field work give so much attention to the physical conditions and the vegetation of the areas studied that they are of interest even to those botanists who have a deaf ear and a closed eye for all of the phenomena of animal life. Dr. Lee R. Dice, of the Kansas State Agricultural College, has published a paper on the Distribution of the Land Vertebrates of Southeastern Washington (University of California Publications in Zoology) which gives some information regarding the vegetation of that region and a few excellent illustrations of it. The field of his work extended from the sagebrush region along the Columbia River, through the grassy plains drained by the Walla Walla River, to the Blue Mountains. It is interesting to learn from this paper that the dissatisfaction with the life zone system, which has been prevalent among botanists for some time, has also appeared among field zoologists. One of the strongest defences of Dr. Merriam's scheme of life zones has been the plea that it is *biological*, and that the primary rôle of temperature as a controlling distributional factor is more strongly played in the animal kingdom than it is in the vegetable kingdom, where moisture relations are highly important. Dr. Dice states, "It has not yet been established that small differences of temperature of the degree supposedly separating some of the life zones are as important barriers to distribution as are some of the more marked differences due to variations in rainfall and humidity." He even goes further and states that " . . . it cannot be considered proved that the temperature relations established by Merriam are the particular ones which determine the limits of distribution of any species of animal."

The Swiss Phytogeographical Commission has issued a program of prospective work on the geobotany of Switzerland, containing a list of works relating to the vegetation of that country and numerous titles of papers dealing with the study of environmental conditions. The admirable and ambitious plans of the Commission provide for exact distributional records, the securing of meteorological data both *in extenso* and *in parvo*, the devoting of greater attention to cryptogams, the harmonizing of the work with economic interests, and the utilization of physiological methods in the study of environmental influences upon plants and plant associations. The members of the Commission are Dr. E. Rübel, Prof. C. Schröter, and Dr. H. Brockmann-Jerosch.

The Textile World Journal describes a new process invented by Prof. James Rossi, of the College of Agriculture at Naples, for retting flax, ramie, china grass and other fibre plants by means of bacterial action. The method is more rapid and dependable than any of the chemical processes now employed, and is superior to earlier methods of bacteriological retting in the nature of the organism employed and in the hastening of its action by the introduction of currents of air into the vessels employed. The precautions used for securing complete asepsis are almost as exacting as those of a surgical operation.

It is announced that arrangements have been made for the preparation of an illustrated flora of the Pacific Coast, similar in character to Britton and Brown's Illustrated Flora of the Northeastern States. The execution of the plan is in the hands of Prof. LeRoy Abrams, who will engage the assistance of other Western botanists. The flora will be published in four volumes by coöperation between Stanford University and the New York Botanical Garden.

Meetings of the Pacific Division of the American Association and of the Western Society of Naturalists will be held at Stanford University on April 4 to 7. A special program will be devoted to papers on evolution and genetics. The last day of the meeting will be devoted to an excursion and a visit to the Field Laboratory of Zoology which has just been established by Stanford University.

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PLANT ASSOCIATION OF WESTERN PENNSYLVANIA WITH SPECIAL REFERENCE TO PHYSIOGRAPHIC RELATIONSHIP

J. E. CRIBBS

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The development of the vegetation of any given region is subject to a number of important factors. The variation of one or more of these may suffice to initiate very noticable changes in the composition of the vegetation.

The water content of the soil, for instance, is the most important single factor influencing plant development; and other conditions being equal, will determine whether the vegetation will be of a desert, prairie, open forest, or mesophytic forest type. The increased available supply of soil moisture, up to a certain point, always affords a proportional increase in the richness and abundance of vegetative development. There are always additional factors, however, which in conjunction with this one, give rise to a wide range of habitats. Of these temperature, exposure to wind, exposure to sun, and soil composition, are of most significance.

One of the striking features which occurs is the close relationship between these physical factors and the local topographical conditions, so that it is customary to encounter a similar combination of factors in like physiographical situations (e.g.: in the ravine, valley, or on the bluff, or flood plain). This general likeness in the combination of factors encountered under similar conditions, produces habitats in which are found characteristic types of vegetation. These vary as the factors vary; but nevertheless there is a striking resemblance noticed when the vegetations of these positions are compared.

Western Pennsylvania may be divided into two general areas: (1) the glacial drift, and (2) the unglaciated clays. The

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former of these regions occupies a zone extending from a point approximately forty miles north of Pittsburg, northward to Lake Erie. It is about thirty miles wide in the central part and gradually diverges northward, following very closely the course of the Allegheny River. The topography is of a rolling morainic character, and the soil a mixture of glacial boulder clays. The latter region borders this on the east, and extends eastward to the Allegheny Mountains, forming the Allegheny Plateau. The soil here is predominantly of yellow clay and the topography very much broken up into rough, irregular, hills and valleys. The altitude of the glaciated region ranges from 573 feet at Lake Erie to 1350 feet in Mercer County, while that of the unglaciated area extends from about 715 feet at Pittsburgh to 1840 feet in southern Warren County.

The following climatic data, compiled from Grove City College records, is worthy of notice since it bears a direct relation to the type of flora developed there as a climax. The table below shows the average rainfall during the months of April to November inclusive. This is the period of the year during which the soil is not frozen and hence retains large quantities of water which become available for vegetative growth.

	inches		*inches*
April	4.12	August	3.61
May	3.60	September	3.91
June	3.52	October	3.03
July	4.73	November	2.05

The average annual rainfall is 41.7 inches.

The average rainfall for above eight months—28.63 inches.

The average annual snowfall is 58.26 inches.

The following average temperatures are given for the months during which the greatest vegetative development occurs.

April	49.53° F.	August	67.10° F.
May	57.40° F.	September	63.60° F.
June	67.70° F.	October	51.65° F.
July	70.00° F.		

The average temperature for these seven months is seen to be 61°, while that of the five months of comparative inactivity is 31.18°. While the average summer temperature is favorable for rich vegetative growth, it is at once evident from the average of the colder months, that conditions are unfavorable for other than a deciduous type of flora.

In accordance with the annual precipitation, its relatively equal distribution through the months of greatest growth, and the favorable temperature during these same periods, there is developed a climax mesophytic forest for this region. It is also typically deciduous; an adaptation suitable to the low average temperature for the five months of dormancy.

It will not be within the scope of this paper to treat exhaustively the various exceptions occasioned by peculiar combinations of physical factors, and the corresponding features in the vegetation. An attempt will be made, rather, to correlate the vegetation of the most important physiographic features to their habitats; to define the generic composition; and to observe the sequence of development.

The specific forms enumerated from time to time as components of particular associations in the various series are not exhaustive, but include in each instance the forms which dominate or are of considerable ecological importance.

THE SWAMP SERIES

LOWLAND SWAMPS

The distribution of swamps in western Pennsylvania is limited largely to the glaciated region. Here the irregular, rolling topography frequently includes small glacial lakes and ponds. The smaller of these have been wholly or partially reclaimed by the natural development of vegetation, so that various stages may be seen from the open swamp to the dense swamp forest.

In Mercer County the area occupied by these is relatively great. The land lies at an altitude ranging from 1100 by 1350 feet and the numerous swampy depressions serve as headwaters for the small streams which flow south, east, and west into the Shenango and Allegheny Rivers.

Many of these included lakes and ponds have long since developed beyond the early stages of reclamation, but are prevented from a rapid advance to a more mature stage by the seepage of water into them from the surrounding morainic clays, or because they are fed by springs. Upon the unglaciated area east of the Allegheny River the topography is rugged, the gradient, steep, and the drainage system more efficient. Hence the development of swamps there is quite uncommon. Glacial lakes which have not advanced far in the process of reclamation frequently show four distinct stages of development, namely—the Aquatics, the Open Swamp, the Shrub Stage, and the Swamp Forest, the last exhibiting Deciduous and Evergreen Types. While these more or less distinct regions are arranged horizontally and in a concentric fashion, they really represent successive phases in the vertical sequence of the plant series.

The Aquatics

The aquatic species are the first to infringe upon both lakes and streams. Because of their habit of growth they may be subdivided into three groups, namely—Submerged Aquatics, Floating Aquatics, and Aero-Aquatics. These are regularly distributed in zonation, in the order given; and constitute an assemblage of plants well adapted, because of their abundant developeent, to fill up shallow water to a stage which admits of the entrance and development of aerial species.

Submerged Aquatics. The submerged aquatics advance far out into the lake. They are attached species with vegetative structures entirely beneath the water surface, but with flowers which develop at the surface. They are mostly annuals, and because of this fact, by their decay in the fall, add yearly to the humus, which by gradually collecting on the bottom raises it's level to a position near the water's surface; thus affording a condition which is conducive to the entrance of the succeeding stages. Among the species encountered here *Elodea canadensis* is the most characteristic both because of it's early entrance and prolific development. The following species are also prominent members in this stage: *Najas flexilis*, *Najas guadalupensis*. *Myriophyllum heterophyllum*, *Ceratophyllum demersum*, *Nitella*, and *Ranunculus aquatilis*.

Floating Aquatics. The zone of submersed aquatics, which constitutes the pioneer stage, is not usually sharply defined from that of the floating-aquatics but overlaps it to a considerable extent.

To this latter group belong not only the few species which float freely upon the surface such as *Spirodela polyrhiza,* and *Lemna minor,* but also those which develop with roots or rhizomes anchored at the bottom and send up leaves which spread out flat upon the water, permitting the direct exchange of gases through their upper surfaces. Many of this assemblage bear two kinds of leaves, the second type being submerged and more finely divided, or smaller than the floating ones. To this zone, besides those already cited, belong the following members: *Nymphaea advena, Potamogeton natans, Potamogeton amplexifolius, Potamogeton angustifolius,* and *Polygonum amphibium.*

Always in association with these, there are found some of the submersed species which persist in the shallower water.

Aero-Aquatics. Following the stage which is dominated by aquatics with floating leaves, occurs a region which is variable in extent—the aero-aquatic zone, or marsh. This stage appears in very shallow water, and the characteristic members develop aerial vegetative leaves which rise from roots or rhizomes that are commonly submerged.

Many of the forms developing here are quite xerophytic in texture and general appearance. This is in part due to the intensity of the light, both incipient and reflected; partly to the exposure to desiccating winds, and partly to the lack of correlation in root and shoot development. Among the species commonly encountered here may be mentioned, *Typha latifolia, Scirpus americana, Scirpus validus, Polygonum Hydropiper,* and *Sium cicutaefolium.*

The Open Swamp

The marsh stage is seldom sharply defined but grades off into the open swamp which more commonly occupies extensive areas. In fact the larger number of western Pennsylvania swamps have advanced beyond the aquatic stages, but retain the open swamp formation for a long period of time. This phase in development is commonly referable to one of three causes: (1) *Because of frequent burning.* Burning strongly inhibits the development of many shrub and tree species. (2) *Partial Submergence.* This follows the melting of winter snows and the occurrence of heavy spring rains. (3) *Raising of the water table.* This is commonly caused by the seepage of water from adjacent regions, or by the presence of springs. It is especially the latter two of these conditions which are responsible for the retention of the open swamp phase.

A very noticable feature of these stages is the development of two types of vegetation; one characteristic of the spring and early summer, and the other of late summer and autumn. The vernal and early summer type is composed primarily of aero-aquatics and species adapted to growing in low muddy or marshy situations. This is made necessary by the great abundance of water present over the area during this season. In the composition of this vegetation there are a number of species which may be considered typical, but as in all plant associations, they vary in different localities, chiefly because of local limits to migration. Among the most representative of the species may be mentioned, *Typha latifolia, Scirpus americana, Caltha palustris, Senecio aureus, Polymonium reptans, Polygonum amphibium, Polygonum Hydropiper, Symplocarpus foetidus, Aspidium Thelypteris, Onoclea sensibilis, Sphagnum, Cicuta bulbifera, Ranunculus septentrionalis, Veratrum viride, Viola cucullata, Saxifraga pennsylvanica,* etc.

Later in the summer the habitat may be greatly changed by the evaporation and gradual drainage of the surplus water, so that the water table is lowered and conditions become much more xerophytic. The relative abundance of vegetation is greatly reduced; and that which remains is, because of its greater openness, subject to very desiccating influences such as intense heat and light exposure associated with a low water content in the soil. These in conjunction with the acidity and low soil temperature initiate the changes in floral composition.

The autumn flora is usually strongly represented by the rushes and sedges. The following species are typical:—*Eriophorum gracile, Eriophorum callitrix, Scirpus sylvaticus, Scirpus atrovirens, Scirpus polyphyllus, Carex gynocrates, Carex tenella, Carex diandra, Carex Frankii, Carex aquatilis, Typha latifolia, Aster puniceus, Spiranthes cernua, Eupatorium perfoliatum*, etc. Many of the rushes develop *hummocks* which are always typical of the open swamp. It is upon these that the seedlings of invading species usually first appear.

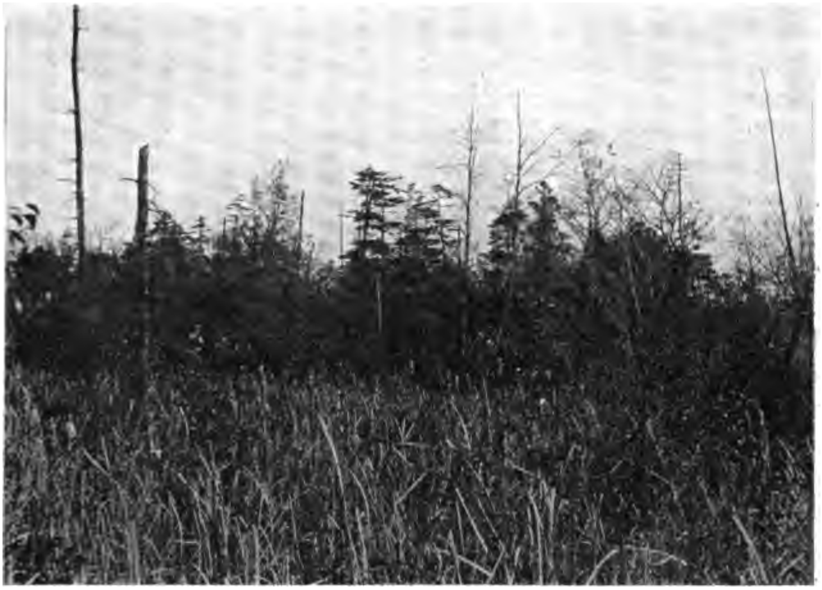

Fig. 1. The open-swamp stage in which *Typha latifolia* dominates. This stage is being replaced by the entrance of *Alnus incana, Betula Lenta,* and *Acer rubrum.*

The Shrub Stage

The open stage very commonly has scattered patches of 'ow shrubs which develop upon the hummocks. These invade from a surrounding zone where this type is dominant in the vegetation. Of these pioneers the most common are *Rosa carolina* and *Cornus stolonifera.*

There is frequently a well defined boundary between the open swamp and shrub stages. In the latter the soil has become more stabilized, but the depressions between the hummocks are commonly flooded in the spring and may remain so for most of the summer, in which case vegetation is limited almost exclussively to the hummocks or is composed of aquatics. The species at this stage of the series include, *Rosa carolina*, *Cornus stolonifera*, *Ilex verticillata*, *Rhamnus alnifolia*, *Chamaedaphne calyculata*, *Pyrus arbutifolia*, *Salix lucida*, *Salix candida*, *Benzoin aestivale*, *Rubus hispidus*, *Aster puniceus*, *Sphagnum*, *Ranunculus septentrionalis*, *Caltha palustris*, *Aspidium Thelypteris*, *Aspidium cristatum*, *Osmunda cinnamomea*, *Osmunda regalis*, *Onoclea sensibilis*, *Symplocarpus foetidus*, *Veratrum viride*, *Viola cucullata*, *Ranunculus*, *recurvatus*, etc.

The species which occur in the depressions are most variable, since they are subjected to the greatest variation in conditions of environment. Frequently *Alnus incana* forms dense stands occupying large areas, and when present usually dominates. It is especially characteristic of swamps which are traversed by small streams, or of undrained areas upon relatively unstable humus. Its most common position is the low boggy humus on either side of swamp streams where it differs from the other members of the shrub stage in that it is not necessarily associated with hummocks.

This cool wet situation is somewhat different from the more removed portion of the swamp for there is a greater circulation of the soil water, and hence a lower acidity. There are associated with this habitat a few forms which are relatively uncommon outside this situation, namely;—*Cardamine pennsylvanica*, *Helenium autumnale*, *Sium cicutaefolium*, *Polemonium reptans*, etc.

The Forest Stage

Deciduous Swamp Forest. Previous to the establishment of the swamp forest there may be considerable instability of the soil. This is due to its being built up from a depth of several feet by the accumulation of a loose humus which has undergone only partial decomposition; and because of its texture and high water holding capacity. Because of this origin the mucky substratum is frequently found to quake in the various stages up to and including that occupied by the shrubs. This condition however has passed and the soil become more compact before the development of the forest stage upon it.

The pioneer trees like their predecessors the shrubs, advance, occupying positions upon the hummocks, while the depressions may remain quite unoccupied for a time. These, however, are eventually reclaimed, the first occupation being made by herbaceous species.

Among the earliest of the tree entrants, *Fraxinus nigra*, *Betula lenta*, and *Acer rubrum* are most conspicuous. *Fraxinus* develops abundantly while young but when well matured, it almost invariably dies, giving a characteristic appearance to this stage by the scattered trunks of the dead and dying trees. The explanation of this behavior is quite uncertain, but it apparently lies in the relation of the root system to the wet swamp soil. So long as the roots of the seedlings are confined to the hummocks the development is quite rapid, but when once the stem has developed so far that the root system must extend itself into the wet boggy humus of the depressions, there generally occurs a

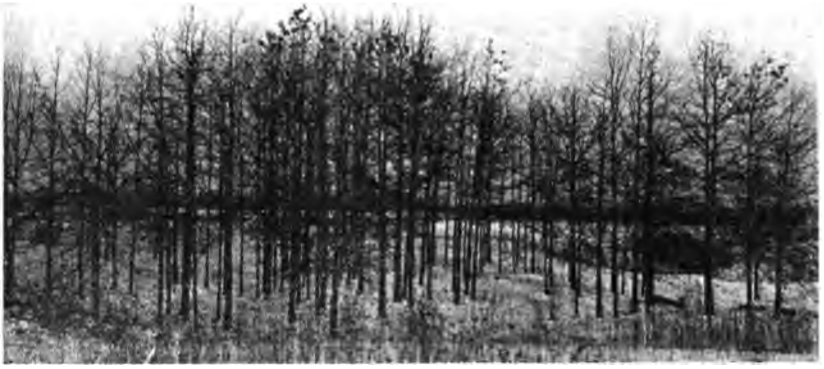

Fig. 2. A late stage in the reclamation of an upland depression, which was formerly a pond. It is occupied here by a pure stand of *Quercus bicolor*.

reaction upon the stem and foliage, and the tree either fails to develop further or gradually dies.

The pioneer tree species are, as a rule, the dominant ones throughout the deciduous stage, especially when it is succeeded by an evergreen one. Accompanying these may also be found, *Betula lutea*, *Larix laricina* and *Ulmus americana*. The latter form being found here but rarely and then usually associated with slight elevations.

The undergrowth of shrubs and tree seedlings is commonly very dense, and may make passage through this stage quite difficult. The essential forms represented here are;—*Rhus vernix*, *Rhus toxicodendron*, *Hamamelis*, *virginiana*, *Vaccinium corymbosum*, *Cornus stolonifera*, *Rhododendron canadense*, *Rosa carolina*, *Prunus virginiana* and *Alnus incana*. With these occur the seedlings of *Betula*, *Fraxinus* and *Acer*.

The herbaceous representatives include, *Viola cucullata*, *Viola pallens*, *Caltha palustris*, *Sphagnum*, *Cirsium muticum*, *Lactuca spicata*, *Polygonum sagittatum*, *Polygonum arifolium*, *Symplocarpus fœtidus*, *Arisaema triphyllum*, *Veratrum viride*, *Ranunculus septentrionalis*, *Ranunculus recurvatus*, *Ranunculus abortivus*, *Senecio aureus*, *Polemonium reptans*, *Mnium*, etc. These are characteristic of the depressions while upon the broad hummocks of the same area are found *Rubus idaeus*, *Medeola virginiana*, *Trillium erectum*, *Mitella diphylla*, *Cypripedium parviflorum*, *Dentaria diphylla*, *Polygonum biflorum*, *Maianthemum canadense*, *Osmorrhiza longistylis*, *Circaea lutetiana*, *Aspidium spinulosum*, *Aralia nudicaulis*, *Osmunda cinnamomea*, *Osmunda Claytoniana*, *Onoclea sensibilis*, *Aspidium cristatum*, *Geranium maculatum*, etc.

Larix laricina, which belongs to the deciduous zone, although of the coniferous type, commonly assumes a position on the inner edge of the zone, adjacent to the true evergreen species. When *Larix* is strongly represented there rarely occurs any deciduous swamp forest of the broad leaved type, except possibly a narrow fringe of more or less scattered forms. This means that *Larix* infringes upon the shrubs, and that the position occupied by *Fraxinus*, *Betula* and *Acer* is, in this instance, largely taken by the tamarack.

Evergreen Swamp Forest. The deciduous type of swamp forest is replaced by one which is predominantly evergreen. It occupies the outer borders of the swamp and constitutes an association which is more persistent than those already described. It is common to encounter a few scattered individuals of *Fagus grandifolia*, *Castanea dentata*, and *Prunus virginiana* here, but these are limited to elevations and represent entrants from the morainic forests without.

The coniferous forest persists as long as does the swamp itself, and cannot be replaced naturally until the true swamp conditions have passed; therefore it may be considered as the climax stage of the swamp series. If succeeded eventually by another stage, it is the deciduous climax forest.

There are two essential tree members of the evergreen forest, *Tsuga canadensis*, and *Pinus Strobus*. *Tsuga* is of much greater abundance than *Pinus*, and follows the *Betula-Fraxinus-Acer* stage more commonly than the *Larix*. It begins as seedlings upon the hummocks. These it eventually broadens and greatly enlarges, thus affording more ample space for the development of herbaceous species which are not adapted to the heavy wet soil of the depressions. *Pinus* is most abundant in Sphagnum bogs where it regularly succeeds *Larix*. It likewise is associated with hummock development.

In contrast to the deciduous swamp forest the evergreen stage is readily penetrable, so far as undergrowth is concerned, since the close stand excludes almost all direct light; thus forbidding the luxurious development of the lower forms.

The undergrowth is likewise essentially evergreen, or largely so. Especially is this true when one considers that which is associated with the hummocks. Here the chief species include *Taxus canadensis*, *Coptis trifolia*, *Lycopodium lucidulum*, *Lycopodium obscurum*, *Aspidium spinulosum*, *Porella*, *Mitchella repens*, *Gaultheria procumbens*, *Sphagnum*, *Trientalis*, *americana*, *Cypripedium acaule*, *Viburnum alnifolium*, *Osmunda cinnamomea*, *Viburnum acerifolium*, *Epipactus repens*, *Trillium erectum*, *Maianthemum canadense*, etc.

The depressions at this stage are frequently carpeted with

Sphagnum or *Mnium*, but may contain herbaceous species which persist from the preceding deciduous stage, especially such as can develop in poorly lighted situations. It should be noted that the large majority of the species represented in the coniferous swamp zone, which are not evergreen, are vernal forms. These develop in greatest abundance along the inner edge where it borders the deciduous stage, and along the outer portion where it grades into the deciduous mesophytic forest of the moraines. This disposition of the species is largely attributable to the fact that they carry on a large part of their physiological work before the deciduous trees mature their spring foliage.

Pinus appears but sparingly in the hemlock stage, unless it be upon slightly elevated ground. It, like the hemlock, has a tendency to develop pure stands, and is found in better established and drier situations. Both of these forms very commonly advance upon the uplands, where they become members of the morainic forests. Such migrations are not very extensive, and these species rarely become dominant members under such circumstances unless special moisture conditions favor this development.

Upland Ponds

Numerous small ponds are formed upon the moraines. They commonly occur where clay lies at the bottom of depressions and is in turn overlain by coarser glacial drift. The seepage of water from the latter may be sufficient to supply the amount lost by evaporation etc., or, as frequently happens, they may dry up more or less completely during the latter part of summer.

The vegetation associated with these has a different aspect from that occuring in the great lowland swamps. There is a notable absence of the sedge-bulrush stages, and a strong development of the shrubby associations. Such ponds are commonly from ten to seventy-five yards in width, and since they are usually surrounded by the morainic mesophytic forest, the humus is built up quite rapidly by the decomposition of leaves and fallen trees, which are added in excess to the humus formed from the decay of plants within the area itself.

As previously stated, the most conspicuous feature is the shrub stage and the strong hummock development associated with it. The aquatic stages may be almost entirely absent; *Lemna minor*, *Spirodela polyrhiza*, and certain algae, being the species present when there is any representation. The reason for the tendency to eliminate the aquatics is perhaps to be found in the acidity of the water. The decomposition of the leaves sets free the chemical materials formed and deposited there as byproducts during their activity in summer. These compounds are largely acid, and are detrimental to the development of aquatic species; or if present in sufficient quantities may entirely inhibit such development.

Upon the hummocks the chief shrubby representatives are *Cephalanthus occidentalis*, *Ilex verticillata*, *Pyrus arbutifolia*, *Cornus stolonifera*, *Viburnum cassinoides, and Vaccinium corymbosum*. In addition to these they may be occupied by *Osmunda cinnamomea*, *Osmunda regalis*, *Woodwardia virginica*, *Onoclea sensibilis*, *Aspidium spinulosum*, *Cypripedium acaule*, and a few others. *Woodwardia areolata* is a rare component in the flora here, although never reported from western Pennsylvania.

The following tree species appear upon the margins of such ponds and succeed the shrubs, *Nyssa sylvatica*, *Quercus palustris, and Quercus bicolor*. During the replacement of the shrubs, pure stands of either *Quercus bicolor* or *Quercus palustris* may occur. Pure stands of this kind are of very frequent occurrence. Later *Acer rubrum* and *Fraxinus nigra* may make an appearance. From this condition there is a direct passage to the mesophytic forest types.

THE LAKE-FOREST SERIES

While the swamp series most commonly occurs in the natural reclamation of western Pennsylvania lakes there is another sequence giving rise to associations of a different nature, which terminates more rapidly in the mesophytic forest of the region. This order is found where there is more uniform and complete drainage than in the cases of swamp successions. This eliminates to a large extent the annual flooding of the region, due to spring rains and the melting of winter snows. Hence it makes possible the more rapid succession. The humus becomes compact at an earlier stage than in the preceeding series; evidently due to the more uniform water table, and the more complete disintegration of organic matter.

The Aquatics

The aquatic stages in this sequence bear a close resemblance to those of the swamp series, and it will suffice in discussing them here to merely allude to some of the differences which may occur.

Among the submersed aquatics there are a number which develop in greater abundance in the lake successions than in the swamp series. This is especially true of those which are inhibited by the presence of acid in the water. Of these *Nitella* is perhaps the most conspicuous.

In the aero-aquatic and marsh zones there are found some differences. In addition to the species already enumerated as characteristic of this position in the former series, there occur a few additional ones which are more strictly limited to fresh water ponds and lakes. Among these are *Pontederia cordata, Sagittaria latifolia, Iris versicolor, Sparganium eurycarpum, Eleocharis olivacea, Cicuta maculata,* and *Castalia odorata.*

The Fen

One of the essential differences in the swamp and lake-forest series occurs in the appearance of a fen instead of an open-swamp stage. The land lies low but is quite firm and is not, as in the latter instance, characterized by the formation of hummocks. The transition from the marsh to the fen is usually gradual and is a change from a rush to a sedge stage.

The flora is typically low and herbaceous, and consists essentially of *Lycopus americanus, Lycopus virginicus, Lythrum alatum, Scirpus americanus, Bœhmeria cylindrica, Radicula palustris, Carex cristata, Carex scirpoides, Carex stricta, Carex crinita, Carex flava, Carex aurea, Verbena hastata, Eupatorium* *perfoliatum, Gentiana Andrewsii, Gentiana crinita* (*rare*), *Asclepias incarnata, Hypericum virginicum, Lobelia syphilitica, Campanula aparinoides, Typha latifolia, Acorus calamus, Gerardia paupercula,* and *Ranunculus abortivus.*

The outer portion of the fen is infringed upon by a belt of shrubs which is usually narrow. It is composed of *Salix glaucophylla, Salix longifolia, Cornus stolonifera, Cephalanthus occidentalis,* etc. The zone of shrubs may be very extensive when the area is low, but commonly forms a mere fringing belt about the edge of the forest which succeeds it, if the slope from the fenland is appreciable. The latter is commonly the case, so that the forest is comparatively well drained and is distinctively of the mesophytic type. This is, in most respects, similar to the floodplain forest which will be discussed later.

The Forest

The forest margin may contain such outposts as *Crataegus, Prunus virginiana, Pyrus coronaria, Populus tremuloides, and Populus grandidentata.* Its inner structure in brief is as follows. The most important tree members are *Ulmus americana, Acer rubrum Tilia americana, Juglans cinerea, Carpinus caroliniana Quercus alba, Quercus rubra, Carya ovata, Magnolia acuminata, Ostrya virginiana,* etc.

The herbaceous representation is dependent upon the density of the forest, but the number of species is commonly large. The vernal flora developed here is very rich and includes among it's members *Erythronium americanum, Phlox divaricata, Viola cucullata, Viola pallens, Viola pubescens, Cypripedium parviflorum, Geranium maculatum, Podophyllum peltatum, Claytonia virginiana, Anemone quinquefolia, Anemone pennsylvanica, Trillium grandiflorum, Trillium erectum, Streptopus amplexifolius, Thalictrum dioicum, Smilacina racemosa, Hepatica acutiloba,* etc.

THE RAVINE-VALLEY SERIES

Most ravines are formed upon slopes with a comparatively steep gradient, where the cutting of a channel is facilitated both because of the inclination, and the great amount of sediment carried. Since the vertical cutting is more rapid than the lateral, small streams of this sort soon become flanked on either side by steep slopes; the steepness being dependent upon the nature of the soil and the position of the rock bed beneath.

When ravines are formed in the rock which underlies a shallow soil, they are characterized by steep or almost vertical slopes; but when formed in the glacial clays, the slopes, steep at first, are much more rapidly eroded as the stream increases in length, and volume of current. Thus, during the later stages of any stream's history there is a series of topographical features always present, each one of which, because of the different physical conditions accompanying it, displays a floral composition of it's own. The clay and rocky ravines will be found on the outer and higher margins of the basin, and are continuous below first with the broad ravine, then with the narrow valley, and finally with the broad open valley where the slopes are of low gradient and the stream has built an alluvial floodplain of the material carried down from the higher levels.

There is a close correlation of the plant associations to the physical factors involved in these habitats; and the variation of certain of these factors, as for instance the position of the water table, or the exposure to direct sunlight, etc., is responsible for accompanying changes in the vegetation.

The Rocky Ravine

Rocky ravines develop where there is an outcropping of underlying rock, or where it approaches close to the surface. They are commonly found on side slopes of broad valleys where the action of erosion by the main stream has exposed the rock strata, and small tributaries entering, have cut their way through.

Such ravines at first are but a few feet in width, and because of the highly resistant character of the rock, the walls are usually quite vertical. By the process of erosion they are slowly broken down and the material resulting from the weathering collects at their bases forming small talus slopes upon which most of the vegetation develops. The narrowness of such de-files, the common presence of water in the stream bed, and the seepage of water from the walls, afford an abundance of available moisture not common to the adjoining regions. Additional features conducive to mesophytism are found in the protection afforded from the wind by the nature of the depression itself, and the prevention of rapid evaporation by the development of a shade along the margins.

During the early stages of such a ravine three plant zones are usually distinguishable. Lowermost is one which is characterized by the presence of the liverworts, *Marchantia polymorpha*, *Conocephalus conicus*, and *Pellia epiphylla.* At this point there is commonly found a deep shade, and plenty of moisture. Immediately above the liverwort zone may occur one in which the dominant forms are mosses. The differentiation of this region sometimes does not occur, so that the mosses appear more or less scattered throughout the lower zone and form a transition directly to the crevice pioneers above. The crevice plants form an assemblage represented by species which develop upon the steep faces of the rock walls, sending their roots into the joint planes and crevices where they depend upon the small amount of humus and the moisture it retains, for their sustenance.

When the rock faces are strongly exposed to the desiccating influences of wind and sun, such pioneers are of necessity quite xerophytic in structure, and restricted in their development. In such situations occur *Aquilegia canadensis, Poa compressa, Verbascum Thapsus, Aster oblongifolius, Aster anomalus, Hedeoma pulegioides, Melilotus alba*, etc. However when this same position is protected by shade there is a distinct mesophytic aspect presented, even by the crevice plants, and one finds *Cystopteris bulbifera, Arabis canadensis, Arabis laevigata, Solidago latifolia, Aspidium marginatum, Aspidium spinulosum, Polypodium vulgare, Asplenium Trichomanes*, and associated with them various lichens including *Endocarpon, Psychia*, etc.

Under the best of conditions the rock walls offer but uncertain anchorage; so that small species are dominant. When, however, the talus formed at the base of the rock walls has accumulated in sufficient quantity, there is initiated a condition more favorable for plant development. The talus is present on one side only during the earliest stages of the ravine, the other being occupied by the stream which shifts its position, removing the weathered rock now from one side and now from the other. As the ravine approaches a width of twenty yards, a talus forms on each side and increases in amount as the weathering process continues Upon the moist talus slope develop numerous mesophytic species such as *Pilea pumila, Cystopteris bulbifera, Smilacina racemosa, Acer spicatum, Aralia nudicaulis, Acer rubrum, Tilia americana, Solidago caesia, Impatiens biflora,* etc.

Broad Rocky Ravine

As a small stream of this sort cuts back it's source, there gradually occurs a widening of the ravine. This comes about through the agency of the underground water, which dissolves out the more soluble portions and causes the rock to break up. This occurs most commonly by their splitting along joint planes. The appearance of shale or less firm rocks beneath may facilitate the process, so that the talus is built up of fine weathered material, intermingled with which are always found great quantities of large and small rocks. When a ravine of this character has attained a width of from one to two hundred yards, the talus is usually still richly supplied with moisture, and there may appear one of two types of flora,—(1) One dominated by evergreens (2) One dominated by deciduous species.

Evergreen Type. Of these the evergreen apparently develops when there is an abundance of cold water seeping through the talus from the upper slope. When this stage appears it generally persists until the ravine has developed into an open valley with a width of a quarter of a mile or more.

The chief members of the broad rocky ravine during the evergreen stage are *Tsuga canadensis, Aspidium spinulosum, Lycopodium lucidulum, Aspidium marginale, Porella, Taxus canadensis, Lycopodium obscurum, Tiarella cordifolia, Polystichum acrostichoides, Pinus Strobus, Clintonia borealis, Clintonia umbellatula, Habenaria orbiculata, Cypripedium parviflorum, Viburnum alnifolium, Viburnum acerifolium, Acer spicatum, Trillium un-*

dulatum, Moneses uniflora, Cypripedium acaule, Mitchella repens, Arisæma triphyllum, Trientalis americana, Sambucus racemosa, etc.

Tsuga frequently develops in so close a formation that it inhibits practically all herbaceous undergrowth, but more commonly the stand is of the above composition in which the dominant forms, both tree and herbaceous, are evergreen. It frequently happens that one encounters a few forms of *Tilia, Acer rubrum, Fraxinus americana, and Castanea dentata* associated with the evergreen assemblage.

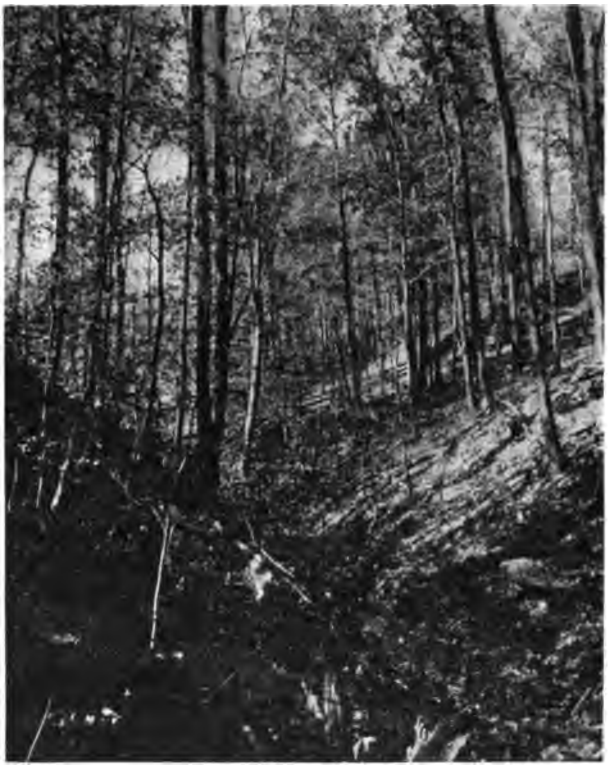

Fig. 3. Narrow mesophytic ravine. The chief representatives here are *Tilia americana, Quercus rubra, Acer rubrum,* and *Castanea dentata.*

Deciduous Type. The development of the deciduous type of flora in the rocky ravine is commonly associated with a lower water content of the soil than is found in those bearing the evergreens. A large number of species and a large number of individuals of each, is a striking feature of the deciduous type as compared to the relatively few species found in the evergreen stages. Then too, there are generally but six or eight species which are very abundant in the latter type, the others being of less frequent occurrence; while a large number are strongly represented in the former.

The most important members of this stage include *Sassafras variifolia, Tilia americana, Fraxinus americana, Acer rubrum, Rubus odorata, Quercus rubra, Prunus serotina, Betula lutea, Betula lenta, Ulmus americana, Hamamelis virginiana, Acer spicatum, Viburnum acerifolium, Sambucus racemosa, Magnolia acuminata, etc.*

Of the herbaceous representatives there is a large number, but since a considerable part of these are also associated with the mesophytic woods of the uplands and the floodplains, it will suffice to note at this point some of those which are most typical. These would include *Aspidium spinulosum, Aspidium marginale, Polystichum acrostichoides, Aspidium Goldieanum* (*rare*), *Asplenium angustifolium* (*rare*), *Asplenium Filix-foemina, Asplenium acrostichoides, Dicksonia punctilobula, Chimaphila umbellata, Cypripedium acaule, Cypripedium parviflorum, Arisaema triphyllum, Pilea pumila, Camptosorus rhizophyllus* (*rare*), *Osmunda cinnamomea, Osmunda Claytoniana, Polypodium vulgare, Psedera quinquefolia, Vitis cordifolia,* and *Impatiens biflora.* The fern members represented here are seen to be numerous—a feature characteristic of the broad ravine with a deciduous flora.

The Clay Ravine

One of the most striking differences between the rocky and clay ravines occurs during the initial stages. The relative instability of the latter does not admit of the formation of vertical slopes. During the thawing in spring, and the period of heavy rains which follows, there may be extremely rapid erosion of the slopes, accompanied by slumping. This is especially true in exposed situations, and the slopes there are practically void of vegetation.

The early stages of the clay ravine are seen to be xerophytic in character. This is true of those which are exposed; but if such development takes place in protected areas, as for example in a mesophytic forest, it may present an entirely different aspect. The erosion here is much slower and is seldom sufficiently rapid to completely remove the humus from the slopes; although there is usually a distinct creep, resulting in a greater

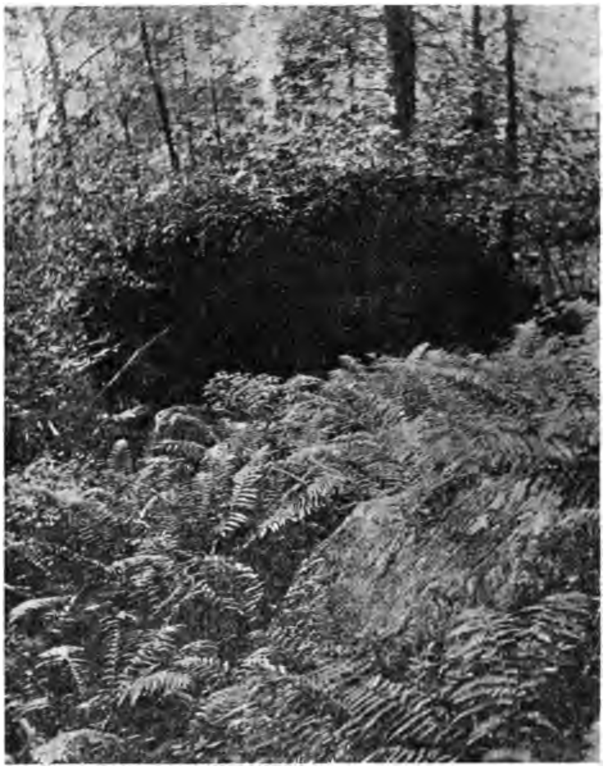

Fig. 4. Undergrowth in the deciduous stage of the broad ravine, showing the prolific development of ferns which is a characteristic feature. *Osmunda claytonia*, and *Polypodium vulgare* are the forms most conspicuous above.

inclination of the trees growing there. In the latter instance the ravine may be distinctly mesophytic throughout its history, and in the former instance eventually becomes so.

In sheltered situations the flora is essentially the same in composition from the early stages to one at which it has attained a width of some forty or fifty yards. As compared to the rocky ravine, the soil moisture is generally less and the humus is not so well developed. The latter fact is due to the creep, which is more pronounced here because of the greater regularity of the slope. The development of an evergreen flora is less common than in the former situation, but may occur where there is a distinct seepage of water.

When compared with the rocky ravine at a similar stage, it is found that the tree representation is much greater, especially as to individuals. When in sheltered places, the species are usually the most mesophytic of the climax forest, and include *Tilia americana*, *Fagus grandifolia*, *Castanea dentata*, *Acer rubrum*, *Prunus serotina*, *Magnolia acuninata*, *Sambucus racemosa*, *Quercus rubra*, etc. The herbaceous species are in large part similar to those of the rocky ravine also, and show a rich fern assemblage. Additional species which are more typical of the clay ravine are *Asplenium platyneuron*, *Epipactus repens*, *Vaccinium canadense*, *Pyrola secunda*, *Aralia nudicaulis*, *Caulophyllum thalictroides*, etc.

The Valley

The development of the valley from the broad ravine stage, infers a gradual transition; just as does the development of the broad ravine by the slow process of lateral erosion of the slopes of the narrower stage. The chief change in the factors which constitute the habitat here as compared to those of the broad ravine are: (1) A greater access of winds, (2) Greater exposure to direct sunlight, (3) Lowering of the water table, especially on the upper slopes of the valley. (4) A higher average temperature with a lower relative humidity.

This combination of factors all tend toward the same result; namely, the production of a flora less mesophytic in composition than that found in the environments afforded by the activities of the earlier stages of the stream. As suggested before, the evergreen stage may persist until the development of the valley. This is not so commonly true of the glaciated area as of the unglaciated region farther east, and seems to be associated with more favorable moisture conditions. For instance, it is frequently retained upon the lower portions of the slope, but gives way upon the higher portions to a deciduous forest as the process of widening continues. The evergreens here retain a structure closely comparable to that described for the ravine stage, but during the transition to the upper zone it becomes more open in formation and the undergrowth as well as the trees indicate a lower mesophytism.

Since the point at which the water table is lowest is near the crest of the valley slopes, the specific forms encountered there have a more pronounced xerophytism. This upper region may be represented by *Quercus alba, Quercus coccinea, Hamamelis virginiana, Prunus virginiana, Castanea dentata, Epigea repens, Pyrus coronaria, Polytrichum commune, Fragaria virginica, Prenanthes alba, Pteris aquilina, Hieracium venosum, Potentilla canadensis, Aster umbellatus, Aster cordifolius, Solidago cæsia, Smilax hispida, Smilax herbacea, Vaccinium vacillans, Corylus americana, Rubus allegheniensis, Verbascum Thapsus, Rubus villosus, Gaultheria procumbens, Epipactus repens, Aspidium noveboracense, Phegopteris hexagonoptera,* etc.

The upper zone is more xerophytic when the lower one is deciduous. The dominant species is regularly *Quercus alba;* and with it may appear *Quercus coccinea, Castanea, Prunus serotina,* and *Quercus rubra,* or they may be absent. The lower slopes when deciduous are represented by such forms as *Tilia, Fagus, Castanea, Acer, Quercus rubra, Betula lenta, Prunus serotina,* and an undergrowth of *Carpinus, Hamamelis, Ostrya,* and numerous herbaceous forms, the composition varying with the factors of the habitat. Even the smaller of the valleys have developed flood plains upon which occur a few species particularly referable to this habitat, such as *Quercus imbricaria Quercus bicolor*, *Ulmus americana*, and *Platanus occidentalis*.

The discussion of the flood plain will be referred to the river series which follows, for it shows its best development along the larger streams.

(*To be continued*)

CRITICAL FLOWERING AND FRUITING TEMPERATURES FOR PHYTOLACCA DECANDRA

FRANCIS E. LLOYD

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The behaviors of the poke-weed (*Phytolacca decandra*) in two diverse climates, widely different from its own, those namely of Tucson, Arizona, and Carmel, California, have been observed for several years by Dr. D. T. MacDougal and the writer. Of these behaviors perhaps the most interesting is the failure to reproduce by seed at Carmel, in contrast with Tucson where fruits and seeds are formed in abundance. At first blush it would seem that this contrast is due to temperature relations, and this turns out to be the case. Indeed, as it has happened, the temperature relations are so clearly indicated in the behavior of the plant at Carmel, that it is possible to determine, within a very small error, the critical flowering and fruiting temperatures. Since the plant grows well enough though not quite normally[1] in this locality, attaining a stature of a meter more or less, and making a consistent, but under the circumstances unsuccessful attempt at flowering, it appears that the failure in this constitutes the factor limiting its ability to persist unaided. Under exceptional circumstances, however, seed may be produced, and it is these circumstances which afford the data herein offered.

Before presenting data, the cogency of which rests upon an understanding of the climate during the growing season at Carmel, a brief summary of this will be given. In the accompanying table, the temperature ranges for ten weeks are spread, together with the numbers of days having temperature ranges included within limits of five degrees as indicated. On days having temperatures not higher than 70° there is usually no sunshine, although on exceptional days there may be an occasional short period scarcely longer than a half-hour, generally less. Such days may be described as fog days. These may be "low-fog" days, or "high-fog" days (to use local terms), Carmel lying directly on the coast and usually overshadowed by the ocean fog-bank, the edge of which reaches a short distance inland. These days, on which one sees the sunlit hills one to three miles distant, constitute about 70% of the whole time, and furnish the dominant climatic conditions. Of direct sunlight, there were during the ten weeks about seventy-five hours, about 9% of the total possible sunshine hours, calling these 12 per day. The distribution of the sunshine hours is also indicated in the table. Of the seventy days, only five (with six hours or more of sunshine) or at most eight (including those with five hours of sunshine) could be called sunshiny.

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[1] Ann. Rep. Dept. Bot. Res. Carnegie Inst. Wash. for 1914, p. 71.

The humidity is usually rather high. On two fog-days, the wet and dry bulb readings were 57° and 63°, and 59° and 66°, or indicating relative humidities of 69% and 66%; on two days of continuous sunshine 62° and 70°, and 63.5° and 74°, indicating relative humidities of 64% and 56%, at the minimal points. At night the temperatures are uniformly low and the dew point is usually reached. There is no rain, though the condensation of moisture on the pine trees during the night is often sufficient to wet the whole surface of the ground beneath. An occasional "weeping fog," enough merely to wet the soil surface, might by the unaccustomed visitor be regarded as rain.

The climate is ideal for many plants, as the luxuriant growth of geraniums, fuchsias, foxgloves and the like shows. It is such cool and humid conditions which make possible along the California coastal belt the growing of beans and many other vegetables to remarkable perfection. But introduced species show a various behavior toward such conditions, as the work at the Coastal Laboratory of the Carnegie Institution of Washington is showing. Of these species, *Phytolacca decandra*, in its above mentioned idiosyncracy, is a striking example.

During five years of observation in the experimental garden no instance of seed development has been found to occur under ordinary conditions. Usually the first inflorescence remains with its flowers unopened but alive for weeks, attaining only small size. Flowers have however been seen to open, and the inflorescence to develop into fair length, on stems which had been accidentally prostrated, evidently as a result of the higher temperatures near the soil surface. Only during the past summer did flowers in this situation succeed in setting seed. It seems evident that the prevailing fog-day temperatures, acting as a limiting factor, are responsible, since when they are slightly raised fruit is developed more or less normally, in spite of the low night temperatures and cold soil. The following exceptions in the general behavior of the plant support this view.

TABLE 1

Temperatures for ten weeks (July 3 to September 10 inclusive), 1916

WEEK	TEMPERATURE FAHR.			NUMBER OF DAYS HAVING TEMPERATURE BETWEEN				HOURS SUN PER DAY
	Day		Night	60–65 (Low) (Fog)	66–70 (High) (Fog)	71–75 (Part) (Sun)	76–80 (Full) (Sun)	
	Maximum	Minimum	Minimum					
1	72	62	42	1	5	1		4–0
2	76	65	47		5	1	1	2–5
3	78	64	44	3	2	1	1	5–4
4	75	60	45	2	3	2	0	1–2
5	71	59	42	4	3			
6	72	62	45	4	1	2		1–1
7	80	68	46		5		2	2–7
8	69	62	50	1	6			
9	78	63	45	2	1	1	3	4–6–6–4
10	82	67	44	0	2	3	2	5–3–6–6–1
Totals......................				17	33	11	9	75

Plants grown within a small glass shelter produced an abundance of fruit quite normal in every detail. The seed was used for propagation, and gave practically perfect germination. About 200 large plants were grown therefrom during 1915–16, none of which set seed, excepting only two plants, to be presently discussed, though inflorescences (but not open flowers) were produced in abundance. The temperature within the glass shelter ranged, on fog-days, about 10° higher at the maximum than without. It is safe to infer that, were the prevailing day temperatures 10° higher at the maximum, *Phytolacca decandra* would grow and reproduce normally.[2] and it may be remarked too that the appearance and structure of the vegetative parts would also be normal. It appears however that a full ten degrees is not necessary.

In 1915 a plant growing outside but quite near to the glass shelter produced on a branch quite close to the wall a single spray of fruit. The inflorescence was so placed as to be sheltered from the down-draft of cool air which is nearly constantly moving down the gulch in which the garden is situated, while it received moreover reflected light and heat from the glass side of the shelter. In 1916, another inflorescence was produced, but was later blasted, after reaching full size and beginning to set seed. It is naturally difficult to get at a precise expression of the temperature differences to which this plant and those nearby, and which did not produce fruits, were subjected. However, by taking wet and dry bulb readings on typical days during the warmest hours, the readings were obtained which are given in table 2.

Repeated readings at various times did not reveal any departures from the above. It appears to be very near the truth to say that, were the prevailing temperatures five degrees higher, fruits and seed would be developed in at least sufficient abundance to insure a population.

This is further supported by the evidence obtained by determining the differences of temperature shown by other adjacent positions in which seed were and were not produced. Of the 200 well-developed plants of 1916 above mentioned, one only had red foliage. These plants, as is usual at Carmel, were checked in their growth with the oncoming of the summer fog after the latter part of May, and in consequence the more terminal leaves formed rather close rosettes, generally with young inflorescences more or less inclosed. In the red foliaged plant only did these flowers open, and evidently started well toward the development of seed, though at length after attaining a length of about 1.5 cm., they failed and remained stunted. In the plants lacking the red pigment the flowers remained unopened. In the former case the red pigment was responsible for ameliorating the temperature conditions. On a high fog day the temperatures indicated by a black and a clear bulb thermometer were 61° and 64° respectively at the height of the flowers, and this difference may be taken to be as wide at any rate as that which would be shown by the rosettes of a green and a red foliaged plant. There can scarcely be a doubt that a prevailing temperature a few degrees, not more than five, higher than 64° would have insured the setting and development of seed in the red foliaged plant.

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[2] *Phytolacca dioica* fruits abundantly at Berkeley.

TABLE 2

	AIR TEMPERATURES	
	Wet bulb	Dry bulb
Low-fog day:		
In draft of air down gulch	54.5	56.0
In protection of glass shelter	57.5	59.5
High-fog day:	Black bulb.	Clear bulb.
In air current	61.0	59.0
	61.0	58.0
In position of developing flowers*	62.5	58.5
	64.0	62.0
Thin fog (faint shadow):		
Near developing flowers†	69.0	66.0
In air current	64.0	61.5

* Seeded in 1915, blasted in 1916.

† Later blasted.

Of the green foliaged plants one had been accidentally prostrated, so that the main stalk up to the first branching lay within 10 cm. of the ground. Thereupon the axillary buds developed a few small leaves and inflorescences. Those lying within 10 cm. of the bare soil surface produced a few seeded fruits, scattered among a majority of blasted ones. It seemed in this case that occasional days, probably grouped in periods of two or three, afforded favorable temperatures within 10 cm. of the soil surface, due of course to the influence of the heat radiated from the soil. The temperature gradient from the soil upwards on a typical high-fog day is indicated in table 3.

Without assuming that the temperatures found on this day were the absolute favorable ones, it may be argued that the temperature differences as between positions 5 cm. and, at most, 20 cm. are sufficient to cause the seeding and non-seeding of the plant, and this difference lies within five degrees at the most. In 1915 a plant was prostrated, and lay on a grassy and therefore cooler surface, and another was purposely so placed. Flowers were formed, but no fruit.

It is therefore concluded that if the prevailing day temperatures at Carmel, California, which are low enough to prevent reproduction by seed, were five degrees higher, during the warmest hours, reproduction by seed would take place at least in sufficient measure to enable the species to persist.[3] The temperatures which permit vegetative activities are not identical with, but are lower than those more intimately connected with reproduction. The more delicate physiological responses shown in anthesis and dependent processes are probably responsible for the frequently observed peculiarities of flowering in many of the higher plants, *e.g.*, the cacti.[4] In the instance before us an illustration is afforded of the possible effect of slightly inadequate temperatures on distribution by inhibiting reproduction.

TABLE 3

	TEMPERATURES	
	Wet bulb	Dry bulb
Soil (1 cm. deep)		82.0
The bulb lying on the surface		
Unshaded		71.0
Shaded		70.0
5 cm. above the surface	63.0	66.0
10 cm. above the surface	57.5	62.5
20 cm. above the surface	56.5	59.0

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[3] Seeds germinate and seedlings develop well in the situation in which flowering and seed-development do not take place.

[4] F. E. Lloyd: Observations on the Flowering Periods of certain Cacti. Plant World **10**: 31–39. 1907.

BOOKS AND CURRENT LITERATURE

The Wilcox Flora of the Lower Eocene.—The flora of the Wilcox formations, recently monographed by Berry,[1] is one of unusual interest to botanists as well as to geologists. This is due to the careful manner in which the flora has been studied and described by Berry, and to the fact that it is one of the largest floras that has been recorded from a single horizon in a comparatively restricted area. It comprises 128 genera in 59 families and 33 orders, more than 94% of which are Angiosperms. Floristically, the Wilcox flora resembles that of parts of tropical and subtropical America, particularly the strand vegetation of the Caribbean coast from Central America to northern Brazil. In addition, the Wilcox flora contains a number of genera, such as *Artocarpus*, *Nipa*, *Cinnamomum*, *Banksia*, etc., which have at present an oriental distribution.

As is well known, there has been in the past considerable controversy in regard to the value of foliar characters as diagnostic criteria. The instability of the gross or superficial characters of leaves has been emphasized by many taxonomists, and by a number of morphologists who have desired to bring into the limelight the conservatism of internal structures. For example, Bentham,[2] after making a very comprehensive study of the Proteaceae, stated in regard to detached leaves, "I do not know of a single one which, in outline or venation, is exclusively characteristic of the order, or of any one of its genera." Seward,[3] the well known English paleobotanist, considers that, "Venation characters must be used with care even in determining classes or groups, and with still greater reserve if relied on as family or generic tests."

In view of supposed difficulties in identifying plants by the impressions of their leaves, the following conclusions of Berry are of considerable interest: "Many botanists love to dwell on the temerity of the paleobotanists in determining species from impressions of leaves. I admit at the outset that some identifications based on fragmentary materials are altogether too uncertain. There is more or less convergence in foliar characters in unrelated or remotely related families and there may also be considerable variation in the leaves of a single species, but foliar characters in general are more fixed than those of almost any other organs of plants. They are subjected to less complex environmental factors and always have been. It should be remembered that characters which are less essential to the vital activities of plants, such as the form of the leaf, when once acquired may continue practically unchanged for thousands of years and afford a surer clue to relationships than characters more immediately within the field of action of natural selection."

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[1] Berry, E. W., The Lower Eocene Floras of Southeastern North America. Professional Paper 91, U. S. Geol. Survey, pp. 481, pls. 116, Washington, 1916.

[2] Bentham, G., Presidential Address. Linn. Soc., p. 17, London, 1870.

[3] Seward, A. C., Fossil Plants, 1: 99, Cambridge, 1898.

Approximately 100, or somewhat less than one-third of the species listed by Berry, are forms which had previously been described by Heer, Hilgard, Unger, Hollick, Knowlton, Newberry, Veatch and Lesquereaux. The investigations of Berry have led him to refer approximately 50% of these forms to different genera from those to which they were assigned by previous investigators. Even more significant is the fact that 40% of the forms have been transferred to different orders.

Such striking discrepancies in the identification of leaf impressions by paleobotanists might easily be considered to indicate that foliar characters are not to be relied upon in determining the relationships of fossils. However, the reviewer is inclined to believe that these discrepancies are largely due to the fact that many of the earlier determinations were based upon more or less fragmentary material and a less comprehensive study of the foliar characters of living plants.

A considerable portion of Professor Berry's monograph is devoted to the description of various orders, families and genera of the Angiosperms, particularly their present distribution and occurrence in various geological formations. This portion of the volume, which has been printed separately,[4] should prove very useful for general reference.

It is to be hoped that Professor Berry will publish the results of his detailed study of the form and venation of leaves, since an accurate key to the plants of the tropics based upon vegetative characters would be of much economic and scientific value.—I. W. Bailey.

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[4] Berry, E. W., The Affinities and Distribution of the Lower Eocene Floras of Southeastern North America. Am. Phil. Soc., 53: No. 214, pp. 129–250, June-July, 1914.

GEOGRAPHY OF THE PERUVIAN ANDES.—The Yale Peruvian Expedition of 1911, carried out under the direction of Prof. Hiram Bingham, was devoted to surveying and geographical reconnaissance along the 73d meridian, which here cuts obliquely across the entire South American Cordillera. Some of the results of this expedition have just been published by Dr. Isaiah Bowman in a form and style which render them of interest to a wide audience.[1] In addition to presenting the results of topographic surveys Dr. Bowman has given an extended account of the development of the physiographic features of the Peruvian Andes, with special attention to the results of glaciation and the erosion produced by snow. The greatest interest of the book, however, lies in its description of the varied topography and climatic conditions of southern Peru, and in its vivid portrayal of the manner in which the distribution of races of men is controlled by these conditions and by the character of the domesticated plants and animals which it is possible to maintain under each of these sets of conditions.

The plains at the eastern base of the Andes are covered by heavy tropical forest of the monsoon type, which extends up to elevations of 3000 to 4000 feet. The direction of the trade winds is such as to bring heavy precipitation and extremely moist conditions to the eastern slopes of the mountains, carrying the forests up to elevations of 10,000 feet and more. The alpine grasslands and shrubbery extend to altitudes as great as 17,000 feet, where Indian shepherds maintain the loftiest permanent dwellings that are known in any part of the world. The Pacific slopes of the Cordillera are extremely varied, being lightly forested at middle elevations, particularly on shaded slopes, and occupied by an extremely light scrub at lower elevations. The deep and narrow valleys are the seats of the principal populations and of the most intensive agriculture. Some of them are situated in moist climates, while others are advantageously located for irrigation. The coastal strip presents extremely desert conditions.

In Peru the vertical limits of the cultivation of familiar economic plants between latitudes of 13° and 16° S. are much higher than in the mountainous regions with which we are more familiar. The banana and the orange are both grown up to about 6000 feet, and sugar cane up to 8000 feet in the valley of the Salcantay. Corn is grown in the Cuzco basin at 11,000 feet, wheat is grown at 12,000 feet, and barley at 13,000 feet, while the cultivation of the native strains of potato is carried above 14,500 feet into the region of nightly occurrence of frost. Arborescent cacti are abundant up to elevations of 11,500 feet, and isolated patches of *quenigo* woodland are found in the cloud belt at 14,000 feet.

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[1] Bowman, Isaiah, The Andes of Southern Peru. Pp. 336, figs. 204, maps 7. New York, Henry Holt and Company, 1916.

It is impossible to give in this place the extended notice which is due the physiographic work accomplished by Bowman. In addition to this material, however, his book is replete with observations of interest to every student of the relation of organisms to environment.—FORREST SHREVE.

TOLERANCE OF FRESH WATER BY MARINE PLANTS.—In a recent paper[1] Osterhout points out that tolerance of fresh water by marine plants is not strictly due to gradual adaptation, as has been supposed. In the case of eel grass (*Zostera marina*), with which the author experimented at Mount Desert Island, Maine, the same differences occurred in the leaves and roots of plants growing in the mouths of streams and plants growing in salt water remote from the mouths of streams, in their ability to withstand fresh water. Eel grass growing in the ocean near the mouths of streams has the leaves immersed in a layer of water that is alternately fresh and salt, and its roots embedded in mud which is almost constantly uniformly saline, while the same species growing away from estuaries has both leaves and roots immersed in a salt medium. Leaf cells in both cases withstand exposure to fresh water for several hours, but root cells are quickly killed. That the longer life of the leaf cells is not due to any difference in cell wall structure is shown by the fact that both leaves and roots were plasmolyzed with equal rapidity when immersed in hypertonic sea water, and then recovered at the same rate when again placed in ordinary sea water. Neither does difference in permeability to water explain difference in behavior, for death is not primarily due to increased water absorption. Following Loeb's point of view, the author suggests that the difference in tolerance of fresh water exhibited by marine plants is due to the difference in outward diffusion from the protoplasm of substances, especially inorganic salts, which are necessary to the normal activity of their protoplasm. Thus the more tolerant plants lose salts less rapidly than those less tolerant of fresh water. He also suggests as the explanation of this effect, that in the protoplasm of less tolerant plants larger amounts of globulins or other colloids may be present which undergo a change of state when the concentration of salts is lowered to a certain point.—LAWRENCE WHITEHEAD.

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[1] Osterhout, W. J. V., Tolerance of Fresh Water by Marine Plants and its Relation to Adaptation. Bot. Gaz. 63: 146–149, 1917.

STRUCTURE OF COAL.—Among the notable achievements of recent botanical effort are Jeffrey's studies on coal. For this work a special technique had to be devised, since the methods of the petrologist had not proved suitable for such friable and highly compressed material. The new method[1] consists essentially in a preliminary swelling by melted phenol or by caustic soda dissolved in alcohol, followed by treatment with hydrofluoric acid and potassium chlorate (or nitric acid) for the purpose of desilicifying and bleaching, after which the material is imbedded in celloidin and the sections cut by means of a microtome. One of the first fruits[2] of the new method was the proof that cannel and boghead coals consist not of algae, as had previously been claimed, but of spores of vascular plants. It has been found possible to distinguish by the microscope coals of different sorts and localities.[3] But more important is the light thrown on the mode of formation of coal,[4] a matter which has been much discussed.—M. A. CHRYSLER.

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[1] Jeffrey, E. C., Methods of Studying Coal. Science Conspectus, 6: 71–76, 1916.

[2] Jeffrey, E. C., The Nature of Some Supposed Algal Coals. Proc. Amer. Acad. Sci. 46: 273–290, pls. 1–5, 1910.

[3] Jeffrey, E. C., On the Composition and Qualities of Coal. Econ. Geology 9: 730–742, pls. 19–22, 1914.

[4] Jeffrey, E. C., The Mode of Origin of Coal. Jour. Geol. 25: 218–230, 1915.

NOTES AND COMMENT

The prize which was offered by The Plant World in November, 1915, for the best paper in soil physics has been awarded to Dr. Howard E. Pulling, of the Department of Plant Physiology of The Johns Hopkins University, for a contribution entitled The Rate of Water Movement in Aerated Soils. The giving of the prize was made possible by the generosity of a friend of this journal who requested that his name should not be used in connection with it. The judges were Mr. R. O. E. Davis, of the Bureau of Soils, Prof. A. G. McCall, of the Maryland Agricultural Experiment Station, and Prof. Charles F. Shaw, of the College of Agriculture of the University of California.

The first number of the Memoirs of the Gray Herbarium of Harvard University is devoted to A Monograph of the Genus *Brickellia*, by Prof. B. L. Robinson. *Brickellia* is a wholly American genus of compositae with 91 species, 35 of which are found in the western United States. This difficult group is treated in a most thoroughgoing manner, with a discussion of the diagnostic value of the various features of habit and structure which is calculated to inspire confidence in the deductions of the author. He remarks "No other feature offers in *Brickellia* so many plausible grounds for distinctions as does the pubescence, particularly the presence or absence of double pubescence, partly glandular and partly non-glandular. Yet these characters, on further examination and especially after the study of much material, nearly always break down hopelessly and are seen to be subject to complete intergradation; and what is more significant appear in many cases to be so readily changed . . . . as to render highly artificial any distinctions based upon them." There is a strong suspicion lurking in the vicinity of much of the taxonomic work of the present day that a similar statement could be made for a great many genera in which differences of pubescence have sufficed to establish specific distinctions.

Prof. Herbert E. Gregory has published the results of his work on the geography and water resources of the Navajo Country, in northeastern Arizona (Water Service Paper No. 380). This region, bounded by the Little Colorado, Colorado, and San Juan rivers, and extending well into New Mexico, is nearly as large as South Carolina, and is one of the least visited and least known areas in the United States. To historians and anthropologists this country has long been of great interest because of its unique Indian villages, which have persisted in a few favored localities for many centuries. Until very recently the natural history of the central and northwestern part of the Navajo country was almost unknown. Professor Gregory's paper comprises a brief description of the types of vegetation and a map showing the distribution of pine, piñon and juniper forests.

The Thirtieth Annual Report of the Bureau of American Ethnology contains a paper which is of interest in connection with a region adjacent to the Navajo Country. This is Mrs. Matilda Coxe Stevenson's Ethnobotany of the Zuñi Indians, a paper which will take a very high place among studies of this kind. Mrs. Stevenson began to work among the Zuñis as early as 1879, when their ceremonials and medical practise had not been modified by the interference of the white man. A remarkable advance had been made by the medicine men in utilizing the plants available to them in treating specific symptoms. They were accustomed to narcotizing their patients before an operation, and were possessed of effectual disinfectants for wounds, as well as cathartics, emetics, remedies for the bites of snakes and ants, and other important specifics. The use of the various food plants is also described, showing that the introduction of corn several centuries ago replaced a diet of the raw or cooked seeds of *Atriplex powellii*, *Chenopodium leptophyllum*, *Artemisia wrightii*, and the grass *Eriocoma cuspidata*. The Zuñis state that "when we depended entirely on the small seeds of plants for our foods, our flesh was not firm and good as it is now." Descriptions are also given of the use of various plants as sources of material for spinning thread, weaving baskets, dyeing pottery, and elaborating the toilets of persons engaged in ceremonial observances.

Among recently issued lists of local floras may be mentioned A Catalogue of the Flora of Isle Royale, Lake Superior, by William S. Cooper; The Flowering Plants, Ferns and Fern Allies growing without cultivation in Lambton County, Ontario, by C. K. Dodge; and A Catalogue of the Plants of Jasper County, Missouri, by Ernest J. Palmer. The first two were published in the Sixteenth Report of the Michigan

Academy of Science, the last in the Annals of the Missouri Botanical Garden.

John Wiley and Sons have recently published a German-English Dictionary for Chemists, by Dr. Austin M. Patterson. It is a handy book of 316 pages, containing not only strictly chemical words but many that are used in plant physiology, agricultural chemistry and mineralogy, as well as the common words which have acquired a technical meaning in these sciences.

Mr. Samuel E. Cassino, of Salem, Mass., is collecting material for a new edition of his well known Naturalist Directory, which he expects to bring out late in the present year. This work comprises both amateur and professional naturalists, and is useful to those who wish to buy, sell, or exchange specimens of any sort.

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THE PHYSICAL CONTROL OF VEGETATION IN RAIN-FOREST AND DESERT MOUNTAINS

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It is possible to compare the physical conditions of two widely separated localities with respect to the influence which these conditions exert upon their respective vegetations without at the same time entailing any comparison of the vegetations themselves. It is the aim of this paper to bring out some of the contrasts between the manner in which vegetation is controlled by the conditions in the humid mountains of a tropical island and in the arid mountains of a temperate continental region. The details upon which these generalizations are based are to be found in the author's publications on the montane rain-forests of Jamaica[1] and on the Santa Catalina Mountains of Arizona.[2]

The point of view of this paper may be indicated by calling attention to the fact that two mountain ranges may differ utterly in flora, and may differ very greatly in vegetation at the same time that the controlling environmental factors are identical in the two. For example, there is a sharp dissimilarity between the San Bernardino Mountains of southern California, and the Santa Catalina Mountains. The latter have only 2% of the species found in the former. The latter have desert and evergreen oak scrub (encinal) where the former have chaparral and nut pine scrub. In spite of these floristic and vegetational differences, however, there is a very close agreement between the relative importance of the various physical factors in these

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[1] Shreve, Forrest, A Montane Rain-Forest: A Contribution to the Physiological Plant Geography of Jamaica. Carnegie Inst. Wash. Publ. 199, 1914.

[2] Shreve, Forrest, The Vegetation of a Desert Mountain Range as Conditioned by Climatic Factors. Carnegie Inst. Wash. Publ. 217, 1915.

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two mountains, and a still closer agreement in the manner in which these factors control the vertical and local distribution of vegetation.

Between two regions as widely separated as Jamaica and Arizona we would expect to find the very great dissimilarity of flora and vegetation that is known to exist. Between the physical controls of the two regions there are also great differences, sometimes even direct antitheses. In the dripping fog-filled forests of Jamaica one would expect to find the local distribution of the vegetation dependent upon a very different set of environmental conditions from those that control the sclerophyllous and semisucculent plants of the arid slopes of the Arizona mountains.

The difference of latitude from 19° N. to 32° N., and the insular position of the Blue Mountains contrasted with the continental position of the Santa Catalinas, lie at the bottom of all else that may be said regarding their dissimilarities. The tropical mountain gradient of temperature renders the summit of the Blue Mountains cool, but very rarely and only locally subject to frost, whereas the whole vertical extent of the Santa Catalinas is exposed to frost and their upper altitudes to relatively severe and prolonged low temperatures. The trade winds of the Caribbean Sea carry a constant and enormous mass of moisture-laden air to the slopes of the Blue Mountains, making their windward side reek with fog and frequent rain, and giving their leeward side a drier, but by no means dry climate. The winds which ascend the Santa Catalina Mountains are both hot and extremely dry, usually exerting a very desiccating effect upon the vegetation of the lower half of the mountain and only occasionally, in the mid-summer or mid-winter rainy seasons, gathering sufficient moisture to cause precipitation.

The climatic conditions of the Blue Mountains are extremely constant when contrasted with those of the Arizona Mountains. The daily temperature curve of the former swings through six to ten degrees, the curve of the latter through forty to fifty-five degrees; and the annual amplitudes are quite as unlike. The frequence and regularity of rain or fog, or at least of heavy cloudiness, cause a period of four or five clear rainless days to be an episode of note to the inhabitants of the Blue Mountains. In the Santa Catalinas a period of four or five days of cloudiness and rain is an even greater rarity, and the rainless periods of the lower slopes often last for eight to twelve weeks. In other words the vegetation of the Jamaican mountains is living under a very uniform set of conditions; it enjoys a climate which is practically seasonless, and is able to prosecute its activities throughout the year. To the plants of the Arizona mountains there come the checks of the winter season and the equally significant checks of the arid seasons; resulting in short periods of great activity and intervening periods of dormancy or of actual injury by drought or cold.

An ascent of either the windward or the leeward slope of the Blue Mountains will bring to notice a gradual change of flora and of dominant species. On the former slopes there will be a relatively slight change in the general physiognomy of the vegetation on passing from the warm lowland rain-forests to the cool rain-forest of the mountains, with its lower stature and greater wealth of pteridophytes, bryophytes and other pronouncedly hygrophilous plants. On the leeward slopes there is a sharp contrast between the savannas and thorn forest of the coastal plain and the evergreen broad-leaved forest of the lowest hills, but there is only a negligible change in the collective ecological character of the forest from an elevation of 1000 feet to some of the localities as high as 6000 feet. The lack of sharp altitudinal changes of vegetation on the two sides of the island serves to emphasize the unlikeness of these sides when compared with each other at any altitude whatever. The contrast is between a pronounced rain-forest, reeking with moisture, and a relatively open and dry evergreen broad-leaved forest. In short, the unlike moisture conditions of the windward and leeward sides of Jamaica cause a sharper differentiation of vegetation than do the altitudinal temperature differences. In this respect the Santa Catalina Mountains are wholly dissimilar from the Blue Mountains, as they have no major climatic influence causing a difference between any portions of them that lie at the same elevation, and they have important groups of both moisture and temperature factors which cause a pronounced vertical differentiation of the vegetation.

Mountains which lie outside the equatorial regions of the earth almost invariably exhibit differences of vegetation on their north-facing and south-facing slopes. These differences, due superficially to slope exposure, are underlaid by complex assemblages of factors which are by no means the same in all of the diverse climatic provinces in which such differences may be observed. The constant direction of the trade wind at Jamaica causes the marked dissimilarity of the north and south slopes which has been mentioned, and thereby masks any effect of slope exposure that would be possible at the low latitude of that island. In the Santa Catalinas, on the other hand, there is a well-marked difference of vegetation on opposed slopes at all elevations. The difference is very conspicuous at certain altitudes, and is commonly about as great as the difference between situations of the same slope exposure which are 1000 vertical feet apart.

One of the most familiar features of the tropical rain-forest is the "stratification" of its various plant types, by virtue of which the dominant trees shelter smaller trees, these form a canopy for tree-ferns or shrubs, these in turn shade large herbaceous plants, ferns or small shrubs, while on the ground itself are the smallest and most hygrophilous of herbaceous plants. In the somewhat stunted forest of the Blue Mountains there is not such a pronounced stratification of the vegetation as may be seen in the richer forests of the lowlands, but it is nevertheless a very noticeable feature of the ravines and more gentle slopes, particularly of the windward side of the range. In the Santa Catalina mountains the lowest, or Desert slopes, and the lightly forested Encinal region are naturally without any stratification of the vegetation, and the pine forests of the higher elevations are as nearly devoid of it as are the pine forests of the southeastern United States. In the heavier fir forests of the highest summits of the Santa Catalinas there is the usual scattering accompaniment of lax and slender deciduous trees and a ground cover of small shrubs and herbaceous plants.

In the Blue Mountains there is a difference of physical conditions between the floor of the forest and its canopy which is sufficiently great to be designated with all propriety as a difference of climate. Instrumental measurement of the daily curves of temperature and humidity on the floor of the rain-forest and in its canopy has been made in connection with a study of the factors controlling the distribution of the filmy ferns.[3] The difference between the highly uniform conditions of temperature and the steadily high humidity of the lowest portion of the rain-forest, and the greater amplitude of both these factors in the tree tops, is undoubtedly exceeded in a striking degree in the loftiest lowland rain-forests. Such difference is paralleled by some of the structural features of the tallest forest trees, of the plants of the middle stratum, and of those residing on the ground or on the lowest portions of tree trunks. It is particularly in leaf structure that such difference is manifested; the trees possess relatively small, heavily cutinized leaves with deep palisade tissue, frequently several layers in thickness, while the undertrees and shrubs have leaves similar to those of temperate deciduous trees, and the herbaceous plants have large thin leaves with a single layer of chlorophyllous tissue and an extensive development of intercellular spaces. These structural differences are chiefly correlated with the unlike water relation of the foliage in the canopy and that on the ground, and with the dissimilar light conditions. The rain-forest, in brief, makes its own climate in so far as the plants of the lower strata are concerned, and the steadying effect which the forest cover has upon the moisture conditions within the forest and in the soil itself is also of vital importance to the dominant trees.

Even in the heaviest bodies of forest which clothe the desert mountain ranges of Arizona there is no difference between the physical conditions of floor and canopy except it be of very infrequent and transitory occurrence. The long rainless periods of the desert are common to the mountain tops as well, although their desiccating effect is lessened by a shorter growing season, by lower temperatures, and by a higher soil moisture at the outset of the dry seasons. The low humidities of the desert are to be found with only slight amelioration at the highest mountain altitudes, and the differences of total wind movements and of the character and intensity of insolation are nearly identical. There are many respects, therefore, in which the controlling physical conditions of the desert are carried with little change to the mountain tops. The forest of the desert mountain does extremely little to make its own climate except in so far as it affords a shade for the herbaceous plants of the closed stands of fir and spruce. In the pine forest of the Santa Catalinas, and to some extent in the fir forest, the herbaceous plants are of a notably xerophilous stamp and with the exception of a very few annuals they are characterized by deep-seated root systems. The lowest stratum of the pine forest is subjected to all of the adverse conditions of water supply and water loss that from time to time affect the trees themselves. The stabilization of climate that is effected by a heavy rain-forest in a moist climate is totally lacking in a desert mountain forest.

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[3] Shreve, Forrest, Studies on Jamaican Hymenophyllaceae. Bot. Gaz. **51**: 184–209, 1911.

An attempt to segregate the various plant communities that make up the collective vegetation of the two mountains under consideration will reveal the fact that in each of them the topographic relief is the first-hand basis upon which such segregation can be most naturally made. In the Santa Catalinas and in the Blue Mountains it is the valley-bottoms, the slopes and the ridges which present the most striking vegetational differences. The vegetational differences correlated with topography are much more striking in the Santa Catalinas than in the Blue Mountains, but this is largely due to the altitudinal interdigitation of the desert, encinal and forest on the Santa Catalinas, as contrasted with a mere difference of composition and stature in a forest of uniform general type in the Blue Mountains.

The great irregularity of the precipitation in Arizona registers its most important effect upon the vegetation in causing great annual fluctuations in the evaporative power of the air and in the moisture of the soil. In Jamaica the soil moisture is uniformly and almost constantly high, so that it fails to operate as a differential factor in the distribution of the vegetation. In spite of the great seasonal fluctuations of atmospheric humidity in Arizona there is a relatively small difference in the values of this factor for any series of locations or habitats at any given time. The great differences in the evaporative power of the air which are found in different locations and at different altitudes are chiefly attributable to wind and temperature. Atmospheric humidity is not, therefore, a differential factor in the desert mountains of Arizona, although it is the strongest single factor involved in determining the habital distribution of plants in the Blue Mountains of Jamaica. The actual factors which underlie the topographic control of the vegetation in the two mountains are therefore diametrically opposed.

PLANT ASSOCIATIONS OF WESTERN PENNSYLVANIA WITH SPECIAL REFERENCE TO PHYSIOGRAPHIC RELATIONSHIP. II

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THE RIVER SERIES

The vegetation associated with physiographical features developed by rivers is in some respects similar to that just described for the valley. There is the young topography of the river, when the eroding or sandy shores are succeeded almost immediately by steep cliffs; and at the other extreme there is the old topography which is characterized by a broad floodplain and low sweeping valley slopes. The stages between these are transitional and are closely comparable to the smaller valley type.

Bluffs

River bluffs may be best studied along the Allegheny River, for throughout much of its course it is included by abrupt slopes which rise from either side to a height of 200 to 500 feet. At most points on the river there is considerable talus formed at the base of the slopes, and the rocks which outcrop here are thus covered in part by loose rocky soil which affords an excellent place for plant development. However, when the outcropping rocks form vertical cliffs, there is presented a situation, which, because of the extreme exposure to desiccating influences, limits the vegetation to a few crevice plants. *Aquilegia canadensis*, *Verbascum*, *Clematis virginiana*, *Ruellia ciliosa*, *Rhus toxicodendron*, *Poa compressa*, etc., may appear in this position.

In striking contrast to the xerophytism of the rock bluffs is the talus below them. This is formed by the accumulation of weathered materials from the cliffs above and hence is practically the same in chemical composition. Except in the more exposed situations, it bears an assemblage of forms which displays a high degree of mesophytism. When such talus deposits come upon exposed points, the water table is lowered, and they bear a flora adapted to dry situations, including with other forms *Rhododendron maximum*, *Kalmia latifolia*, *Melilotus alba*, *Equisetum arvense*, *Aster Shortii*, *Aster Drummondii*, *Aster oblongifolius*, *Vaccinium pennsylvanicum*, *Quercus velutina*, *Quercus alba*, *Clematis virginiana*, *Pteris aquilina*, etc.

When the talus occurs in protected positions, it is usually well supplied with moisture which enters from the layers of stone and shale above. This environment is well adapted to sustain a dense stand, and under such favorable conditions the vegetation is luxuriant. *Rhododendron* and *Kalmia* develop profusely here, occupying especially the rocky portions of the talus near the river banks. Other conspicuous members include *Tilia*, *Magnolia*, *Acer rubrum*, *Acer saccharinum*, *Betula lenta*, *Betula lutea*, *Querçus alba*, *Quercus rubra*, *Fraxinus americana*, *Tsuga canadensis*, *Juglans nigra*, *Prunus serotina*, *Sambucus racemosa*, *Ribes Cynosbati*, *Aralia racemosa*, *Aspidium marginale*, *Aspidium spinulosum*, *Asplenium Filix-fœmina*, *Tiarella cordifolia*, *Arisæma triphyllum*, *Habenaria orbiculata*, *Habenaria Hookeri*, *Osmorhiza longistylis*, *Gaultheria procumbens*, *Cypripedium acaule*, *Trillium undulatum*, *Vitis vulpina*, *Psedera quinquefolia*, *Rhus toxicodendron*, *Smilax hispida*, *Liriodendron tulipifera*, *Polystichum acrostichoides*, etc.

One noticeable feature associated with the talus, is the prolific development of the lianas. They reach their strongest development on the talus and frequently, when exposed cliffs appear above, clamber up the surface, or more commonly descend from above and by developing a shade upon the cliffs aid greatly in retaining moisture, so that the crevice species are better enabled to retain their position. A second feature characteristic of the rocky river slopes is the abundance of *Rhododendron* and *Kalmia*.

Not uncommonly the river bluff is of a different nature from that already described. Steep slopes may occur where sandstones of fine stratification, and shales outcrop. Here, unequal erosion gives rise to small shelves which collect the weathered material, and thus forms a slope of which a considerable part has a shallow soil and humus that are relatively unstable. This is rendered more so by the seepage of water from the rock. Very frequently in the spring landslides occur, caused by the saturated soils higher up on the slope loosing their stability and sliding to the bottom under the force of gravity. Such slides are destructive to the vegetation as they not only completely uproot all plants in their path, but remove the humus and soil, so that the rock is left bare where they have passed. A single cliff of this kind may show evidences of a dozen or more of such slides.

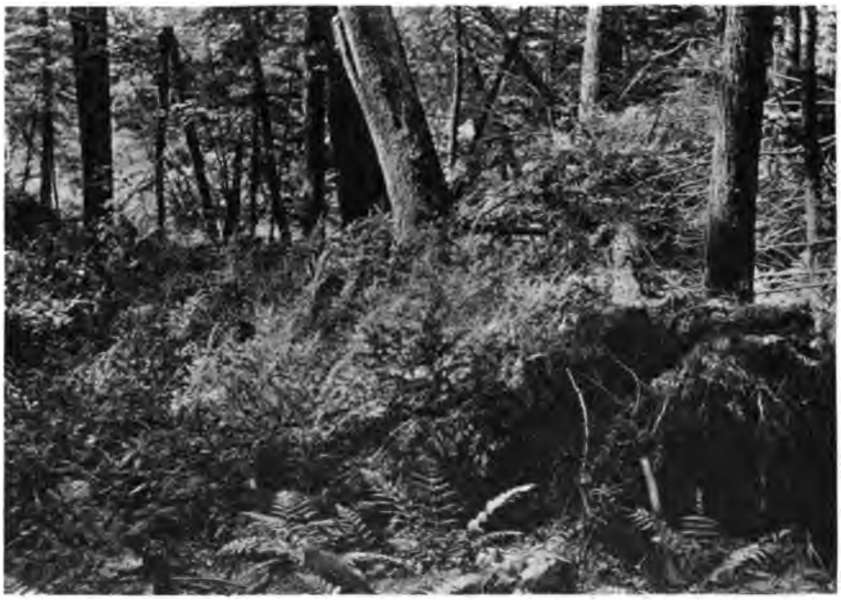

Fig. 5. Undergrowth in the evergreen stage of the broad ravine. This type is characterized by a low number of species most of which are evergreen. The forms represented here are *Taxus Canadensis*, and *Aspidium Marginale*.

It is at once evident that an environment of this kind is not well adapted to the development of a dense forest. The moisture is sufficient, and the desiccating influences frequently not too great, but the instability of the soil together with its shallowness forbid such a type; and instead there occurs a vegetation rather low, more or less open, and in some respects not unlike that occurring in the deciduous forest stage of the swamp series.

The composition here is usually as follows: The chief tree representatives: *Betula lenta*, *Acer rubrum*, *Tsuga*, and *Prunus virginiana*. The following members when represented occur upon the upper portions of such slopes: *Quercus alba*, *Quercus velutina*, *Amalanchier canadensis*, *Prunus pennsylvanica*, *Populus tremuloides*, *Populus grandidentata*, *Rhus typhina* and *Quercus coccinea*. The herbaceous and shrubby species most typical of these steep, moist slopes include *Aspidium spinulosum*, *Osmunda cinnamomea*, *Silene virginiana*, *Lonicera americana*, *Lonicera Sullivantii*, *Lonicera dioica*, *Smilacina racemosa*, *Conocephalus conicus*, *Pellia epiphylla*, *Aster junceus*, *Solidago Drummondii*, *Rubus idæus*, *Agrimonia gryposepala*, *Cornus stolonifera*, *Gaylussacia*, and *Vaccinium*.

Flood Plains

Flood plains are most extensively developed by rivers during their late history when they flow through broad winding valleys. The gradient of the stream is then low and the valley slopes long, low, and sweeping. They appear much earlier in the history of the river, but it is in the broad river valleys that the most characteristic plains appear. Their topography is practically level and the soil chiefly alluvial in nature. When the river has too low a gradient, and does not cut a channel of considerable depth, the plain is submerged during periods of high water. Under these conditions the water table is high, and the area is broken up by the presence of loops and old channels, which retain water and give the whole region a low swampy aspect. Very commonly, however, there is a channel eroded through the plain to sufficient depth to retain the water during ordinary stages; so that it is only at rare intervals of flood that the upper portion of the plain is submerged. The deepening of the river's bed insures better drainage of the plain, and together with the relative freedom from submergence, permits of a development of vegetation far in advance of that occurring upon the lower flood plains.

Three general regions are distinguishable. Each bears a definite relation to the stages of the river, and is characterized by a typical flora. The three regions are: (1) the Littoral Zone; (2) the Transition Zone, (3) the Upper Floodplain.

The Littoral Zone. By the littoral zone is meant that part of the plain immediately next the river, where there is a direct effect upon the vegetation by the waters of the stream at its ordinary levels. Locally this zone might well be subdivided into three or four parts which bear the same relationship to each other as do those of the lake successions. It is only in slow streams or along protected banks that there is a considerable development of submersed aquatics. When represented, the chief components are *Elodea, Nitella, Myriophyllum, Ceratophyllum,* and *Polygonum amphibium.* The aero-aquatics and floating aquatics are commonly more evident and include *Nymphea advena, Potomageton natans, Potomageton americanus, Potomageton obtusifolius, Sagittaria latifolia, Scirpus validus, Typha latifolia, Sparganium eurycarpum,* etc. They occupy the same relative position as in the lake series. Upon the banks of the stream appear a few forms characteristic of this position, such as *Salix nigra, Acer saccharinum, Cornus stolonifera,* and *Platanus occidentalis.* Associated with these is commonly found *Mentha spicata, Lycopus americanus, Laportea canadensis, Polygonum virginianum,* etc.

The Transitional Zone. The transitional zone may be well defined or not but comprises the area submerged by the river during periods of high water. It usually has a vertical elevation of from 4 to 10 feet above the normal level of the river. To many forms the frequent inundation is detrimental, hence they are excluded from this region. The species are largely herbaceous and include *Polygonatum virginianum, Ambrosia trifida, Lysimachia Nummularia,* etc. Of the few shrub species represented *Salix* and *Cornus stolonifera,* are most common in occurrence.

The Floodplain Forest. The floodplain proper lies outside of and above the transition zone. Its soil is alluvial and usually bears a mesophytic forest. One would naturally expect this; first, because of richness of soils of this type, and in the second place because of the water supply which is generally favorable for such a growth.

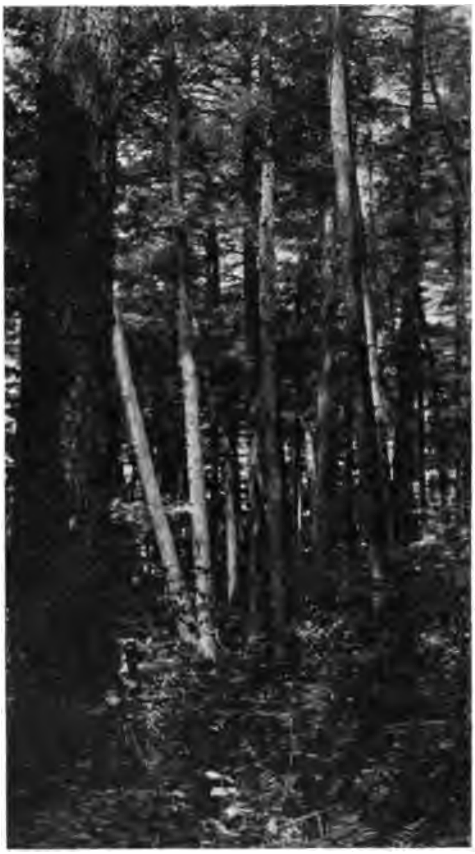

Fig. 6. A pure stand of *Tsuga Canadensis* occurring as the first stage on the slopes of the Allegheny Plateau.

The floodplain is subject to occasional submergence, but it is only during exceptionally high stages that the upper portion of this area is inundated. This occurs mostly at the time of heavy spring rains before the appearance of the vernal flora; and, excepting the mechanical effect of the impact of floating ice upon the trees near the channel, seldom has much direct effect upon the vegetation. The period of submergence is usually too brief, and the amount of sediment deposited at the time of the recession of the waters to the original channel is generally insufficient, to injure the development of vernal species.

In composition the forest of the floodplain is typically mesophytic. Among its members are a few species which are especially characteristic of this situation, and a large number which are typical of the mesophytic forest in general. Of those especially referable to this habitat may be mentioned *Ulmus americana*, *Platanus occidentalis*, *Acer saccharinum*, *Juglans cinerea*, *Quercus bicolor*, *Iris versicolor*, *Acer saccharum*, *Carya ovata*, *Carya laciniosa*, *Salix nigra*, *Mertensia virginiana*, *Echinocystis lobata*, *Polygonatum commutatum*, *Acorus calamus*, *Lobelia siphilitica*, etc. Of these *Carya*, and *Acer saccharum*, are generally dominant species and not uncommonly form almost pure stands.

The remaining members of the forest are largely representatives of the mesophytic deciduous forest of the uplands also; and, as an account of the composition there will be given under the discussion of that subject, it will suffice here to note some of the general features only.

Perhaps one of the most noticeable features of the floodplain forest s the unusual assemblage of vernal species. The rich humus and alluvial soil afford an excellent environment for the development of this type. One encounters the following species here, and frequently in great abundance: *Phlox divaricata*, *Viola cucullata*, *Viola pubescens*, *Viola pallens*, *Erythronium americanum*, *Geranium maculatum*, *Podophyllum peltatum*, *Claytonia virginiana*, *Anemone quinquefolia*, *Anemone pennsylvanica*, *Trillium grandiflorum*, *Trillium erectum*, *Streptopus amplexifolius*, *Thalictrum dioicum*, *Smilacina racemosa*, *Hepatica acutiloba*, *Mertensia virginiana*, *Senecio aureus*, *Dicentra Cucullaria*, *Cypripedium parviflorum*, *Botrychium virginianum*, *Panax trifolium*, *Iris versicolor*, *Anemone thalactroides, etc.*

It is at once seen that although the floodplain forest includes the larger number of the upland mesophytic species, the dominant members are different. That is, *Acer saccharum*, *Carya ovata*, *Ulmus americana*, *Juglans cinerea*, *Platanus occidentalis*, *Quercus bicolor*, and *Acer saccharinum*, are dominant and characteristic members in the former, while those most representative of the latter are *Fagus grandifolia*, *Acer rubrum*, *Magnolia acuminata*, *Castanea dentata*, *Quercus alba*, *Liriodendron tulipifera* and *Quercus rubra*.

THE UPLAND FORESTS

The upland forests of western Pennsylvania may be divided into two types with reference to the topography and soils upon which they occur: (a) The morainic forests, or the type occuring as a climax upon the glaciated area of the western most part; and (b) The forests upon the unglaciated clays.

Upon Morainic Soils

If the chemical composition of the soil is the chief factor in determining the type of vegetation it shall bear, one might reason that the morainic clays would be characterized by a flora of closely smilar composition over wide areas; for these soils are relatively uniform in composition, and at the same time are usually well represented by all the essential elements. This is due to the fact that they are composed of a mixture of soils brought together by the glacier from widely separated points. There is no such uniformity, however, but various topographical features with the same soils, regularly show a change in composition. For instance, that occurring upon exposed upland slopes has a very different makeup from that characteristic of wooded depressions, and that of level uplands has many features uncommon to either.

It is the forest occupying gently rolling areas which shows the climax development of the region; for those occurring in other situations are advanced to this type eventually, as the topography changes. The climax forest is deciduous and contains four conspicuous members, namely, *Acer rubrum*, *Quercus alba*, *Fagus grandifolia*, and *Castanea dentata*. There are additional species always present; some of which are more mesophytic than these; and in such instances they are usually forms typical of the moister depressions such as *Tsuga*, *Tilia*, *Fraxinus*, *Magnolia*, *Liriodendron*, and *Pinus*. Other components of the forest with a lower degree of mesophytism include *Carya ovata*, *Carya alba*, *Carya glabra*, *Quercus imbricaria*, *Quercus rubra*, *Cornus florida*, *Ostrya virginiana*, *Prunus serotina*, *Carpinus caroliniana*, *etc.*

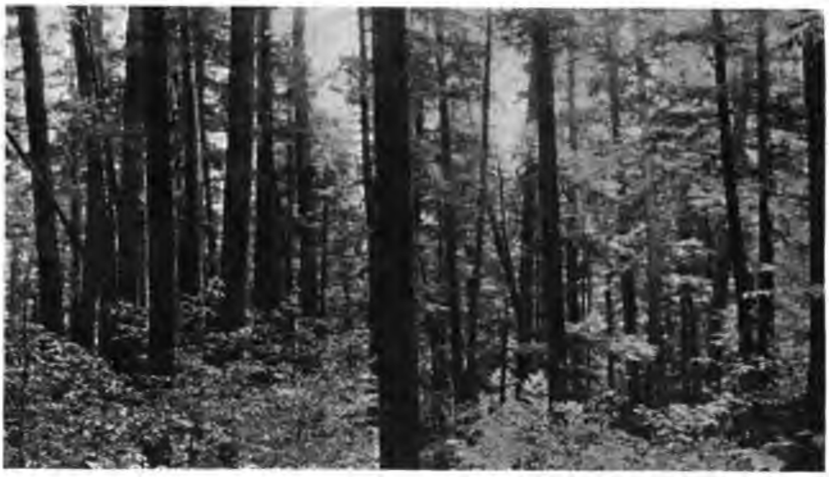

Fig. 7. The white-pine—hemlock stage, which follows the *Tsuga* formation. A pure stand of conifers which will ultimately be replaced by *Acer rubrum*, *Magnolia acuminata*, and *Fagus grandifolia* as indicated by the undergrowth.

Of the four dominant tree members, *Fagus*, *Quercus*, *Castanea*, and *Acer*, the last two are found as components in the flora in almost all situations developed on morainic topography. The beech is more mesophytic, and has a tendency to avoid the dry exposed slopes; assuming rather a position with more favorable moisture relations such as is afforded upon the rolling upland or upon the moist slopes of valleys. The white oak is least mesophytic of these and develops in purest stands upon the higher slopes where the water conditions are less favorable for the beech. The chestnut and maple have the ability to adapt themselves to the rich mesophytic forest, or to the more exposed slopes of the uplands.

The shrubby and herbaceous flora necessarily varies in composition as the tree membership varies; but is always conspicuous for its large number of species. The following forms include the more important members: *Hamamelis virginiana, Ribes gracile, Ribes oxycanthoides, Ribes floridum, Rubus idæus, Rubus allegheniensis, Smilax hispida, Smilax herbacea, Lycopodium obscurum, Lycopodium lucidulum, Lycopodium complanatum, Lycopodium clavatum, Lonicera americana, Mitchella repens, Psedera quinquefolia, Pteris aquilina, Botrychium virginianum, Fragaria virginiana, Osmorhiza longistylis, Aralia nudicaulis, Podophyllum, Anemonella thalictroides, Oakesia sessilifolia, Arisæma triphyllum, Geranium maculatum, Cypripedium acaule, Bœhmeria cylindrica, Uvularia grandiflora, Uvularia perfoliata, Onoclea sensibilis, Aspidium spinulosum, Aspidium noveboracense, Phegopteris hexagonoptera, Polygonatum biflorum, Polystichum acrostichoides, Smilacina racemosa, Osmunda Claytoniana, Osmunda cinnamomea, Medeola virginiana, Trillium grandiflorum, Trillium sessile, Viola pubescens, Viola pallens, Carex pennsylvanica, Maianthemum canadense, Monotropa uniflora, Epifagus virginiana, Aster umbellatus, Aster cordifolius, Solidago cæsia, Prenanthes alba, Prenanthes altissima, Habenaria Hookeri, Epipactus repens, Sambucus racemosa, Asplenium Filix-fœmina, Asplenium platyneuron, Trientalis americana, Gaultheria procumbens, Polytrichum commune, Corallorrhiza maculata, Galium circæzans, Carex platyphylla, Carex pennsylvanica, Euonymus obovatus, Vitis labrusca, Rhus toxicodendron, Tiarella cordifolia, Mitella diphylla, Circæa lutetiana, Streptopus amplexifolius, etc.*

Upon Unglaciated Clays

To the east of the glacial drift the topography is strikingly irregular, being cut up into a great series of hills and valleys by the erosive activity of numerous small streams. Clay soils predominate throughout most of this region. The structural arrangement of the underlying rocks is such as to give rise to numerous springs and a strong seepage of water from many of the slopes. The elevation of this area ranges from about 750 feet at Pittsburgh to 1850 feet in southern Warren County. Because of the complete dissection of this region into hills and valleys, it has a topography very unlike the glacial worked soils, and the disposition of the flora is likewise striking and characteristic. Three vertically disposed stages occur here, namely (a) An evergreen forest stage, (b) A mixed (or transition) forest, (c) A deciduous forest.

The Evergreen Forest

The evergreen forest occupies the lowest position on the slopes; and extends from their bases to a height of some 150 feet, or in some cases even to the height of 350 feet. The soil is decidedly rocky; and with an abundance of cool water supplied by seepage, produces an environment which is closely similar to that existing in the rocky ravine of the glacial zone. The white pine-hemlock forests appearing here are the most valuable of any in Pennsylvania. The large stands of primaeval pines in Forest and Warren Counties are perhaps the finest large tracts of this timber available; and from an ecological as well as economic standpoint are of the greatest interest. They are the deepest shaded forests in western Pennsylvania and necessarily demand of the undergrowth a high ability for development under poor light conditions.

These forests are striking in that the number of species represented is very low, and, because on the whole, the floral composition is less variable than that of any other situation. The lower portion of the evergreen zone is dominated by *Tsuga*, which develops forming a very close stand, or even one which is quite pure. *Betula lenta*, and *Betula lutea*, are the only deciduous trees represented here, and occur along the borders of the streams and in the small ravines upon the slopes. The lower strata of the forest like the upper, are prevailingly evergreen; the dominant species being but four in number, namely, *Lyco-*

podium lucidulum, *Aspidium spinulosum*, *Viburnum alnifolium*, and *Oxalis acetosella*. Accompanying these may be found in greater or lesser amount, *Habenaria orbiculata*, *Tiarella cordifolia*, *Mitella diphylla*, *Maianthemum canadense*, and *Clintonia borealis*.

The seedlings present in the undergrowth of this stage are predominantly of *Betula* and *Tsuga*. Occasionaly those of *Fagus*, *Acer rubrum*, or *Magnolia* occur; but these are unable to develop to maturity except when an opening is afforded, as in a windbreak. The birch and hemlock alone are well adapted to this situation and they successfully retain it against the invasion of outside forms. The seedlings of both of these species have the peculiar habit of germinating on old stumps or fallen logs, thus avoiding the necessity of contending with rival species for a position during their early development. When the old stump decays, the new member has already taken the position of the old one; or when the log upon which such seedlings are developing falls upon the humus, the root system quite readily extends itself into the soil and makes possible the further development of the seedlings concerned.

While the lowest portion of the slope is almost exclusively represented by *Tsuga*, at the height of approximately 80 feet, *Pinus Strobus* becomes sufficiently abundant to be conspicuous. From this point of entrance it occurs associated with the hemlock to the top of the ridge, or may be replaced at a higher level by a deciduous stage.

The Mixed Forest

It is in the pine-hemlock zone just before the entrance of the pioneer deciduous forms that the finest timber occurs; the pines frequently attaining a height of 175 feet and a diameter of 5 to 6 feet, while the hemlock may attain an equal diameter and a height of 150 feet.

The mixed forest consists largely of evergreens, especially in the lower portion of the zone. The conifers gradually decrease, however, with the increase of altitude; and there occurs a proportionate increase in the representation of deciduous species until they entirely replace the former. This mixed type of forest commonly extends from a point about 100 feet above the bottom of the slope to a height of 250 feet or even as much as 450 feet. The lower border is determined by the entrance of *Acer rubrum* and *Fagus,* both trees of distinctly mesophytic character. *Magnolia* gains an entrance slightly higher on the slopes and is soon followed by *Quercus rubra.* *Betula lenta* commonly extends throughout the mixed forest stage, occurring most abundantly in wet depressions and the numerous small ravines. An essential fact that should not be overlooked is, that the deciduous members of this stage are our most mesophytic trees, and species which occur as regular components in the climax deciduous forest of the moraines.

The disposition of the undergrowth when considered from the lower to the upper portions of this stage, also shows transitional features. In the deep shade of the pine-hemlock-beech-maple stage it is closely similar to that accompanying the evergreen formation on the lower slopes, being low and dominantly evergreen; but as the deciduous members become more prominent the lower stratum likewise undergoes a change. *Lycopodium, Clintonia,* and *Viburnum,* are gradually replaced by different species; the latter two by other species of the same genus, namely, *Clintonia umbellatula,* and *Viburnum acerifolium.* Numerous new species are added to the flora and include *Actæa alba, Geranium maculatum, Lycopodium obscurum, Polygola pauciflora, Sambucus racemosa, Streptopus aureus, Lonicera americana, Trillium undulatum, Viola pubescens,* etc.

Tree seedlings constitute most of the woody undergrowth, so that in addition to the shrubby species already cited, *Kalmia latifolia, Smilax hispida,* and *Rhododendron maximum* are the only forms of frequent occurrence. Seedlings of *Fagus, Acer, Magnolia, Tsuga,* and *Betula,* are conspicuous throughout this zone, but those of *Pinus Strobus* are relatively scarce.

The Deciduous Forest

As previously stated, the conifers are generally replaced on the higher slopes by a stage which is typically deciduous. It should be noted, however, that *Tsuga* and *Pinus* persist through the mesophytic stages; so that the upper deciduous forests are quite xerophytic in comparison with those of the preceding zones. The humus is not so well established, nor is the available supply of soil water comparable to that of the areas just described.

The dominating species here are usually *Quercus alba* and *Castanea dentata.* Associated species occurring in greater or lesser abundance are *Quercus velutina, Quercus rubra, Magnolia acuminata, Fagus grandifolia, Prunus serotina, Amalanchier canadensis, Fraxinus americana, Sassafras variifolia, Cornus florida, Carpinus caroliniana, Ostrya virginiana,* etc. The seedling representation suggests a relative permanency of this stage, since it is quite the same as that of the adult assemblage.

The undergrowth of shrubs and herbs includes among other species, the following: *Clintonia umbellulata, Aralia nudicaulis, Aspidium marginale, Aspidium spinulosum, Cornus canadensis, Fragaria virginiana, Gaultheria procumbens, Hieracium venosum, Lonicera americana, Maianthemum canadense, Medeola virginiana, Mitchella repens, Polygonatum biflorum, Polystichum acrostichoides, Prenanthes alba, Pteris aquilina, Ribes Cynosbati, Rubus allegheniensis, Smilacina racemosa, Solidago cæsia, Uvularia sessilifolia,* and *Vaccinium vascillans.*

SUMMARY

The plant associations of western Pennsylvania bear a close relationship to the topographical features of the region; so that a particular type of vegetation may be expected in similar environments, although widely separated.

The fact that distinct types of vegetation and flora are thus associated with any given contour feature is referable to its close relationship to the factors which bear directly upon plant activities. For instance, the environment to which growing plants are subjected in the ravine is closely similar, whether the ravine occurs upon the glacial drift at an altitude of 600 feet, or upon unglaciated clays at an altitude of 1500 feet. The difference in the factor or temperature is but slight; the subjection to desiccating influences is very similar whether it be a question of access of wind or sun. The relative humidity, in so far as there is any appreciable difference, resolves itself into a question of soil moisture. So far as soil composition is concerned, the variations are in no instance striking. The greatest factor determining the composition of the associations is soil moisture, and the greatest differences in the disposition of the vegetation may be assigned either directly or indirectly to this factor.

In the case of ponds and swamps there occurs an interesting relation. The aquatic condition, or the high saturation of the soil, inhibits the process of oxidation; so that the acids and other by-products of the plant's activities accumulate more rapidly than they can be removed by chemical reduction. These substances perhaps have a direct influence upon the vegetation developing there. It is at least apparent that the consumption of what oxygen is available by the process of decay, lowers the amount in the water. so that it becomes more difficult for the plants to secure a sufficient amount. It is primarily because of the undrained condition of such areas, however, that these detrimental materials are retained in an objectionable form, for they are soon leached out of soils when they are properly drained.

The determination of an evergreen forest or a deciduous one as found in ravines and valleys, appears also to be closely associated with soil moisture. There seems to be a modifying factor here,—presumably not so much the temperature of the atmosphere as the relative coldness of the waters which seep from the ravine slopes.

Similar topographies usually mean similar combinations of physical factors; and like combinations of physical conditions mean the recurrence of a given type of vegetation. Although always of the same type, there usually occur slight differences in composition; a fact attributable to unequal or local distribution.

The vertical disposition of the three types of forest on the unglaciated foothills is interesting, in that they are quite comparable to associations on the morainic soils. For instance, the lower zone bears a close relation to the evergreen association in the broad rocky ravine; the mixed forest is closely comparable in many ways to the climax mesophytic forest, containing as it does the most mesophytic of the deciduous trees of this region; and the upper deciduous forest has a composition similar to that of the drier slopes upon the moraines. The major factors in determining the association in each of the instances are the same, namely, the available soil moisture, and exposure to desiccating influences, especially the wind.

The climax formation of western Pennsylvania is a mesophytic deciduous forest of which *Acer*, *Fagus*, *Castanea*, and *Quercus* are the dominant members, but always occur associated with additional species.

The composition of the climax formation is not directly referable to physiographical conditions but to *climatic* ones; and in accordance with the annual rainfall (41.7 in.), its relatively equal distribution during the months of greatest vegetative activity, and the average temperature for the period of growth (61°F.), this type is to be expected.

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BOOKS AND CURRENT LITERATURE

Climatic Conditions as Related to Plant Growth.—The recently published work of McLean[1] marks a new departure in the precise experimental study of a subject which has heretofore been treated mainly by general statistical methods. Nine stations were selected in different parts of Maryland, each possessing a long series of climatological observations. Four plants were grown at each of these stations and subjected to accurate growth measurement. The soil conditions were made uniform for all of the cultures by transporting Norfolk sand for use at each station. The soil moisture was maintained at a continuous optimum in the pots by use of the auto-irrigator. The regular meteorological observations were supplemented by readings of evaporation from the porous cup atmometer. Each culture was allowed to grow for four weeks, being measured as to size and leaf area at the end of the first fortnight, and similarly measured at the close of the second fortnight, together with a determination of the dry weight.

The data which have been published relate only to the growth of soy-bean at two of the stations—Easton, located at an elevation of 32 feet on the Delaware-Chesapeake peninsula, and Oakland, at an elevation of 2500 feet on the Allegheny plateau. The length of the growing season employed at Easton was 171 days and that at Oakland 103 days. For the first fortnight of growth the Easton climate produced a mean leaf area which was 33.3 % greater than that secured at Oakland. When the length of the growing seasons is taken into account the efficiency of the Easton climate is 2.21 times that of the Oakland climate. The published data make it possible to correlate each of the five growth criteria with each of the climatological elements and with such derived climatic features as the ratio of rainfall to evaporation, sums of effective temperature, etc. All of the growth criteria exhibit a seasonal march from low values to mid-summer maxima, falling again in the latter part of the growing season. The last fortnightly period at Oakland exhibited higher temperature and greater growth than the last week at Easton. The maxima of temperature and growth occurred about a month earlier at Oakland than at Easton These are both facts of great importance in the application of phenological data to agricultural problems.

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[1] McLean, Forman T., A Preliminary Study of Climatic Conditions in Maryland, as Related to Plant Growth. Physiol. Res. **2**: 129–208 (No. 4), 1917.

The evidence for soy-bean showed the growth of the first fortnight to be controlled by temperature and that of the second fortnight by the rainfall-evaporation ratio. The securing of facts of this character will make invaluable additions to our meagre knowledge of what may be designated as the physiological life histories of plants. McLean's work emphasises the fact that we must reckon not only with the complexities of the environmental conditions but also with the changes in the requirements of the plant itself from germination to maturity. The publication of his results with Windsor bean, corn, and wheat will be awaited with interest, for in them we will doubtless have to face a third set of complexities—those by which various species of plants differ in their environmental requirements and in their ontogenetic changes of requirement.—FORREST SHREVE.

LABORATORY MANUAL OF SOIL BIOLOGY.—The last five or six years have witnessed the appearance in this country of many laboratory manuals or guides for the student of soil microbiology. Prior to the publication of the Soil Bacteriology Laboratory Guide by Lipman and Brown in 1911, there were no publications of the sort in English. Since then, however, there have appeared in quick succession the number above given. Some of these manuals, to be sure, comprised exercises in several branches of agricultural bacteriology, including soil bacteriology, but at least three have been devoted solely to the last named subdivision of bacteriology.

The subject of the present review is the most recent addition to the group of little volumes referred to.[1] It consists primarily of the usual exercises given to the advanced student of soils in our laboratories on ammonification, nitrite formation, nitrate formation, denitrification, symbiotic and non-symbiotic nitrogen fixation, cellulose decomposition, sulfofication, desulfofication, iron oxidation, and carbon dioxide production. Added to these as new features, are exercises on the study of soil protozoa, soil fungi, enzyme activity of soil microörganisms and more elaborate directions for chemical and bacteriological methods, and for the preparation of media, than are given in

[1] Whiting, A. L., Laboratory Manual of Soil Biology. Pp. ix + 143. John Wiley and Sons, New York and London, 1917 ($1.25).

the other three manuals on soil bacteriology. The problems and questions given at the end of every exercise are also more elaborate and thorough than those of the other manuals. The references given with every exercise, however, are by no means complete enough and offer no improvement over those, for example, given in Burgess' Manual of Soil Bacteriology.

On the whole, Mr. Whiting's little book is well arranged, well printed, and well bound and calculated to serve the student at the present time. The writer of this brief review questions, however, the need for another work of this kind now, even allowing for the slight improvements which the book possesses over its predecessors. Soil biology is admittedly a science in its formative stages, and if it was attempted to prepare a new manual for every novel exercise or two as these appeared every year, we should be swamped with such works in a short time. The making of laboratory manuals can in my opinion easily be overdone. Moreover, many of the subjects now included in such manuals as the one under review are soon to be, if they are not already obsolete and of little significance.—CHARLES B. LIPMAN.

NOTES AND COMMENT

Exercises were held at the Brooklyn Botanic Garden on April 19 to 21 in dedication of the new laboratory building and plant houses. The laboratory building will accommodate the library and herbarium, laboratory rooms for morphology, physiology, and genetics, rooms for instruction and exhibition, as well as a children's room and a public lecture hall. The exercises epitomized the work of the Garden, embracing addresses on topics that have to do with the popularisation and dissemination of botanical knowledge, and also a series of three sessions for the reading of scientific papers. Some thirty-nine titles were read, embracing subjects in nearly all departments of botanical activity.

Almost 200,000 cords of wood are consumed every year by the wood distillation industry in New York State, according to a report just published by The New York State College of Forestry. The woods principally used are maple, birch and beech, the first giving the largest amount of acid from which the final products are refined. Waste from sawmills in the hardwood regions is sometimes used, but pitchy and soft woods such as pine and spruce are undesirable because of their low yield of products. The crude acid which is one of the first products of distillation is combined with slaked lime to form acetate of lime, which in turn is sold to the manufacturers of acetic acid. The acid is used in the manufacture of white lead and acetone, and has a wide variety of uses in the textile and leather industries and the manufacture of smokeless powder and other explosives. Wood alcohol is another of the valuable materials obtained from the distillation of wood, being used in the manufacture of paints and varnishes, dyes, formaldehyde and photographic films, and in the stiffening of hats. Wood tar and wood gas are two of the minor products which are principally used as fuel at the distillation plants. The possibility of such a close utilization of all parts of the tree in this industry makes it possible to manage timber lands on a basis of great economy.

The rapidly growing list of books in the Rural Science Series, which is being edited by Prof. L. H. Bailey and published by the Macmillan Company, has been recently augmented by the appearance of a handbook entitled Strawberry-Growing, by Prof. S. W. Fletcher, of Pennsylvania State College. All of the practical aspects of strawberry culture are given thorough treatment. The books on horticulture which did such good service a generation ago—as, for example, Peter Henderson's Market Gardening for Profit—gave one set of recommendations and cautions for all users of the book. Professor Fletcher's book is like others in the same series in giving specific attention to the distinct requirements of strawberry culture in the different parts of the United States and Canada.

A bulletin of the Agricultural Experiment Station at Amherst, Mass., prepared by Prof. George E. Stone, treats the selection, planting, diseases, and care of shade trees in an exceptionally thorough manner. The methods of tree surgery are fully explained and some interesting facts are brought out regarding the direct and indirect injuries caused to trees by electric currents and arc lamps. It is to be hoped that the newer states will learn to emulate the painstaking care that has long been given shade trees in New England.

Dr. N. M. Fenneman has recently published a map of the physiographic divisions of the United States (Annals of the Association of American Geographers, Vol. 6). The map shows divisions of three orders and is accompanied by a full discussion of the features that have been used as a basis for the demarcation of these areas. The map and text constitute the report of a committee of five men appointed by the Association of American Geographers to carry out this work, which possesses importance in many branches of biological investigation.

A Dictionary of Plant Names has been prepared by H. L. Gerth van Wijk and published by Martinus Nijhoff, of the Hague. The two volumes give cross references involving the Latin names and the names in Dutch, English, French, and German.

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AN ENUMERATION OF THE PTERIDOPHYTES AND SPERMATOPHYTES OF THE SAN BERNARDINO MOUNTAINS, CALIFORNIA

S. B. PARISH

San Bernardino, California

The name San Bernardino Mountains is applied to that part of the southern Sierra Nevada between the Cajon and the San Gorgonio Passes, a distance of some 50 miles in a nearly east and west direction. Their general ridge line is 4000–6000 feet above sea level, but at their eastern extremity they culminate in the twin peaks of San Bernardino and San Gorgonio (or Grayback), respectively 10650 and 11725 feet high. The distance north and south across the mountains is about 20 miles. The curving southern and western ridge rises from a base 1200–1500 feet in altitude and overlooks the San Bernardino Valley; from a like base the eastern acclivities of the terminal peaks face the Colorado Desert; on the north they have a higher base, 3500–4000 feet in altitude, and look out upon the Mojave Desert. On all sides the ascent is abrupt, and there is no proper foothill region.

Except for limited outcrops of limestones, sandstones and conglomerates at a few places along the southern base, the rocks are of the granite series, often exposed in naked masses. The resultant soils are stony, coarse and porous for the most part, but in the valley bottoms they are finer and contain more or less humus. All the streams have eroded deep channels, the larger profound and steep cañons. The general aspect of the mountains is extremely rugged.

The streams have their sources in numerous mountain valleys, most of them of small size. Bear Valley is the largest of them, and has a length of 10 miles and a width of 1 or 2. The upper end of it is occupied by a "dry lake" of the same type as those

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of the Mojave Desert, which its rim looks out upon; but the climatic conditions cause this lake to be filled more frequently and deeply and to retain its water for longer periods, sometimes for several years. The flora of this end of the valley is much affected by the proximity of the desert. The lower part of the valley was formerly a green subalpine meadow, a sedgy pool in the center; now all is submerged beneath the deep waters of a great reservoir. This appears to have effected the extinction of some of the plants which formerly grew here. The flora of the mountains is being further modified by the inroads of the thousands who now resort to them for their summer vacations.

Fig. 1. Winter view of the San Bernardino and San Gorgonio Peaks from the San Bernardino Valley

It is to be regretted that records relating to the meteorology of these mountains are few, and for altitudes above 6500 feet entirely wanting. Table 1 presents the mean precipitation at two stations in the mountains, and for comparison that at San Bernardino, at their southern foot, and at Barstow, the nearest available station on the Mojave Desert, not far from their northern base.

From this table it is seen that the precipitation at Bear Valley is nine times as great as that at Barstow, more than twice that at San Bernardino, and one and three-tenths greater than that at the station on Mill Creek near the base of the mountains. The altitudinal distance between the last station and Bear Valley is 3550 feet, and the increased rainfall at the higher of them is 8.24 inches. The summit of San Gorgonio is 5224 feet above Bear Valley, and with the same proportionate increase of rainfall it would receive 11.85 inches more than the Valley, or a total of 44.57 inches, which is probably less than the actual amount. At all altitudes above 3500–4000 feet nearly four-fifths of the precipitation is in the form of snow, which melts promptly at the lower limits, but on the high peaks lingers into early summer, and often later on northern exposures. Most of the precipitation on the highest mountains finds its way into the Santa Ana River, which seeks, but seldom reaches, the Pacific Ocean; the rest of it is carried by the Whitewater and is absorbed by the sands of the Colorado Desert. The valleys which drain to the north are the headwaters of the Mojave River and their outflow would be carried by it to the great depression of Death Valley, but under present climatic conditions ages have elapsed since that destination was attained.

TABLE 1

Mean monthly and annual precipitation in inches

STATION	ALTITUDE IN FEET	YEARS OF RECORD	JULY	AUGUST	SEPTEMBER	OCTOBER	NOVEMBER	DECEMBER	JANUARY	FEBRUARY	MARCH	APRIL	MAY	JUNE	ANNUAL
Barstow.........	2,150	19	0.14	0.16	0.23	0.44	0.27	0.61	0.58	0.46	0.57	0.10	0.05	T	3.61
Bear Valley Dam..........	6,500	20	0.22	0.68	0.57	1.37	2.39	3.61	7.18	4.56	8.87	1.54	1.58	0.17	32.74
Mill Creek.......	2,950	10	0.13	0.09	0.79	1.07	1.29	2.53	4.58	3.70	6.82	2.12	1.22	0.16	24.50
San Bernardino.	1,054	42	0.03	0.17	0.17	0.60	1.37	2.59	3.33	2.86	2.92	1.19	0.58	0.08	15.89

Records of temperature are still more imperfect than those of precipitation. At Little Bear Valley (5500 feet altitude) the recorded extremes are 93° to $-2°$ F. At Bear Valley (6500 feet altitude) there is no high record, but for low $-14°$ F. These records cover a period of six years only, and give but an approximation to the value of the temperature coefficient. There are no records of the atmospheric humidity, but this must of necessity be low in a limited area surrounded by extensive regions of great aridity.

It will be readily understood that this narrow ridge, however lofty its summits, facing on every side deserts and arid hills and plains, can have no other than a xerophytic flora; and such, with but few exceptions, is its character. The great majority of the plants—trees, shrubs and herbs—exhibit in various degrees the familiar modifications characteristic of xerophylly.

For the same topographical reasons the zonation of this flora is far less well defined than that of mountains more favorably situated and of greater extent. Yet nowhere else in America save on the adjacent San Jacinto Mountain, is there displayed in such close conjunction so wide a range of phytogeographic regions. The two deserts at the north and east are occupied by a Lower Sonoran flora, and members of it and cognate species abound on the sides of the mountains which face them; the flora of the opposite base is Upper Sonoran and greatly, but not as greatly, modifies that of the southern ascent. The less tilted area between is covered by a Transition coniferous forest; above this, on the flanks of the culminating peaks, the Canadian and Hudsonian regions are represented; and at the very summit of San Gorgonio, above the tree line, are to be found a few Arctic-Alpine plants. From various local conditions this zonation, especially above the Transition, is interpenetrating and often confused, but it has a real and distinguishable existence.

In the following catalogue an attempt is made to define the zonal distribution of the different plants, so far as the writer's knowledge of it permits. Further investigations will doubtless correct the assigned distribution in some instances, but it is believed to be fairly accurate.

The southern slope of the mountains is covered with a close growth of shrubs, the trees and herbs being mostly confined to the bottoms and sides of the numerous cañons, most of which carry permanent brooks. This is called the Chaparral Zone; the Lower Chaparral extends from 1500 to nearly 3000 feet altitude, and the Upper Chaparral thence to the ridge line. The former subzone is characterized by such shrubs as *Adenostoma fasciculatum*, along its lower limits, and above by *Juglans californica*, *Ceanothus crassifolius*, and *C. divaricatus;* the Upper by *Pseudotsuga macrocarpa*, *Umbellularia californica* and *Ceanothus integerrimus*.

The opposite, or desert slope is also overgrown with shrubs, but of species entirely different from those found on the southern side. It is designated the Piñon Zone, and its altitudinal limits are between 3500 or 4000 to 6000 or 7000 feet in various parts. Among its notable plants are *Pinus monophylla*, *Fremontia californica* and *Ceanothus Greggii*. The subzones are not well distinguished, but such plants as *Salvia pilosa*, *Purshia glandulosa* and *Pentstemon Eatoni* are found only in the Lower, and *Brickellia oblongifolia linifolia*, *Malvastrum Davidsonii* and *Caulanthus crassifolius glaber* only in the Upper. The cañons of this slope, that of the Mojave River excepted, are without permanent streams, save occasionally for short distances, and even springs are infrequent; but their flora is more abundant and more varied than

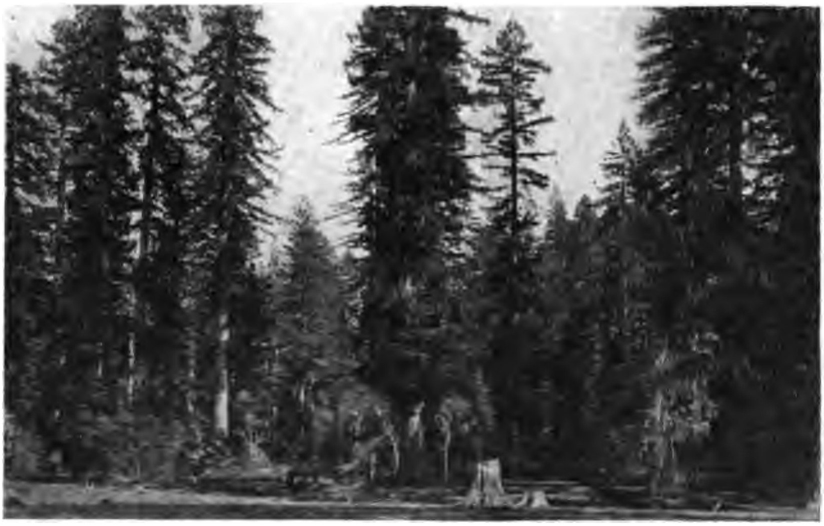

Fig. 2. Forest of yellow pine in the Lower Transition Zone

that of the dry ridges and hills. Though arid the cañon soils are relatively moister than those of the hills and the shelter of their cliffs and steep sides affords a varied environment conducive to a diversified plant life.

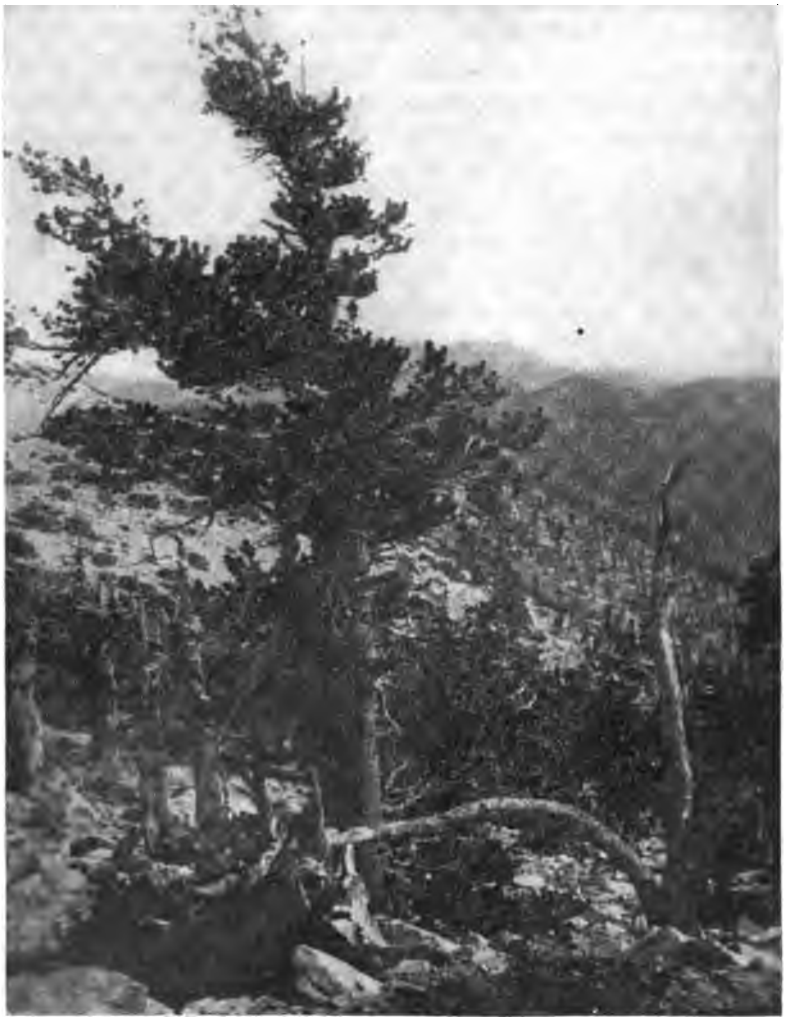

Fig. 3. Alpine slopes of San Gorgonio Peak, with open forest of limber pine

The limits of the Transition Zone are approximately between 5000 and 7000 feet altitude. They are occupied by a forest of mixed conifers, the dominant tree being *Pinus ponderosa;* in the Lower subzone are found *Cornus Nuttallii*, *C. californica* and *Quercus Kelloggii* and in the Upper *Juniperus occidentalis*, *Cercocarpus ledifolius* and *Ceanothus cordulatus.* At about 7000 feet begins the Canadian Zone, with *Pinus murrayana* as its index, and at about 9000 to 10000 feet this merges into the Hudsonian, which extends nearly to the summit of San Gorgonio, and is indicated by the presence of *Pinus flexilis.* These two zones are much confused, and their limits poorly understood. Finally at the very summit of San Gorgonio is a feeble representation of the Arctic-Alpine flora.

In the following catalogue the term "zone" is used for convenience to denote areas of unequal phytogeographical value. But few common names are given, for the reason that but few are in popular use, and the function of the botanist is not to provide such names, but to record those actually in general use.

CATALOGUE

OPHIOGLOSSACEAE

Botrychium simplex E. Hitchc. Am. Journ. Sci. **6**: 103.

In a cañon of South Mountain, Mill Creek, *G. R. Robertson*, and Big Meadows, *Hall*, both in the Canadian Zone; but few plants in either place.

POLYPODIACEAE

Polypodium vulgare Linn. var. *hesperium* Nels. & Macbr. Bot. Gaz. **61**: 30.

In rock crevices in the Hudsonian Zone.

Polypodium californicum Kaulf. Enum. Fil. 102.

Abundant in shaded rock crevices in the Lower Chaparral Zone.

Gymnogramma triangularis Kaulf. Enum. Fil. 75. Gold Fern

Abundant in shaded gravelly or stony soil in the Lower Chaparral Zone. Only the yellow-powdered form is found.

Notholaena tenera Gillies, Bot. Mag. t. 305.

A few plants only, in rock crevices in Cushenberry Cañon and Water Cañon, both in the Lower Piñon Zone.

Adiantum capillus-veneris Linn. Sp. Pl. 1096. Maidenhair Fern

Occasional on the face of shaded dripping cliffs in the Lower Chaparral Zone.

Adiantum pedatum Linn. Sp. Pl. 1095.

Snow Cañon, an Hudsonian island of Mill Creek Cañon.

Pteris aquilina Linn. var. *lanuginosa* Hook. Fl. Bor. Am. **2**: 196. Bracken

A low form prevails as a ground cover in the open pine forest of the Lower Transition Zone, and a more luxuriant form is frequent about springy places and on stream banks in the Lower Chaparral Zone.

Cheilanthes Fendleri Hook. Sp. Fil. **2**: 103, t. 107 B.

Frequent in crevices of rocks in the Upper Chaparral and Transition Zones, and occasional in the Piñon Zone.

Pellaea andromedaefolia Fée, Gen. Fil. 129.

Frequent on shady and stony hillsides in the Lower Chaparral Zone.

Pellaea ornithopus Hook. Sp. Fil. **2**: 145 A.

Abundant, usually in the shelter of shrubs or stones and in clay soil, in the Lower Chaparral Zone.

Pellaea wrightiana Hook. var. *californica* Lemmon Ferns Pac. Coast 10.

Occasional in exposed rock crevices, or in rocky soil, in the Canadian Zone.

Cryptogramma acrostichoides R. Br. App. Frankl. Journ. 767.

Infrequent in the Canadian and Hudsonian Zones. Big Meadows; Dollar Lake.

Woodwardia radicans Smith, Mem. Acad. Turin, **5**: 412.

Frequent about springs and on shaded stream banks in the Lower Chaparral Zone.

Asplenium filix-foemina Bernh.; Schrad. Neues Journ. Bot. **1**: 26. Lady Fern

Occasional about springs and streams and in bogs in the Transition Zone.

Dryopteris filix-mas Schott. Gen. Fil.

Among rocks, Upper Holcomb Valley, a single collection, and the only one reported from the state.

Polystichum munitum Presl. Tent. Pterid. 83.

Common on shaded stony cañon sides in the Chaparral Zone.

Polystichum scopulinum Maxon, Fern Bull. **8**: 29.

Locally abundant in rock crevices at the Hudsonian island in Snow Cañon.

Aspidium rigidum Swartz var. *argutum* Eaton, Wheeler's Surv. **6**: 333.

Common on shaded and stony cañon slopes in the Chaparral Zone.

Cystopteris fragilis Bernh.; Schrad. Neues Journ. Bot. **1**: 26.

Frequent in damp crevices and on stony stream banks in the Transition Zone.

Woodsia oregana Eaton, Canad. Natur. **1**: 91.

Rare on rocky cliffs in the Canadian Zone.

EQUISETACEAE

Equisetum arvense Linn. Sp. Pl. 1061.

Occasional, and sometimes locally abundant, in wet soils, in the Chaparral, Transition and Canadian Zones.

Equisetum Funstoni A. A. Eaton, Fern Bull. **11**: 10.

Rare in sandy soil in cañons of the Lower Chaparral Zone.

Equisetum robustum R. Br.; Engelm. Am. Journ. Sci. **46**: 88.

Infrequent in mucky soil in the Lower Chaparral Zone.

SELAGINELLACEAE

Selaginella Bigelovii Underw. Bull. Torr. Club **25**: 130.

Abundant in the shelter of stones and shrubs, and in rock crevices, in the Lower Chaparral Zone.

Selaginella Watsoni Underw. Bull. Torr. Club **25**: 127.

Frequent in crevices of rocks in the Hudsonian and Alpine Zones, and in the Hudsonian island in Snow Cañon.

ISOETACEAE

Isoetes Bolanderi Engelm. in Parry, Am. Natur. **8**: 214.

Formerly in the shallow stream which drained Bear Valley, which is now deeply submerged by the reservoir. Probably extinct; not otherwise known in southern California.

PINACEAE

Pinus Coulteri Don, Linn. Trans. **17**: 440. Big-cone Pine

Irregularly distributed, in large or small groups, throughout the Transition Zone. A tree 40–60 feet high.

Pinus flexilis James, Long's Exped. **2**: 35. Limber Pine

Near the summit of San Gorgonio Mountain between 10000–12000 feet altitude, and characterizing the Hudsonian Zone; also in the Hudsonian island of Snow Cañon, at 6500–7000 feet altitude. A tree 15–30 feet high; often prostrate at its upper limits.

Pinus lambertiana Dougl. Trans. Linn. Soc. **15**: 500. Sugar Pine

Scattered, mostly singly, throughout the Transition Zone, preferring the moister and richer soils of flats and ravines. The largest tree in these mountains is a Sugar Pine of more than 7 feet diameter growing near Strawberry Flat. This species attains a height of 100–200 feet.

Pinus monophylla Torr. & Frem. Frem. 2d Rept. 319, t. 4. Piñon

Common in arid soil in the Piñon Zone, of which it is the characteristic tree. A short-trunked tree 15–35 feet high.

Pinus murrayana Balf. Rept. Oreg. Exped. 2, t. 3. Tamarac Pine

Common in the Canadian Zone, of which it is the characteristic tree. A spreading tree 50–75 feet high.

Pinus ponderosa Dougl. in Lawson, Man. 355. Yellow Pine

The dominant tree in the open coniferous forest of the Transition Zone, and passing into the Canadian. A massive tree, 100–150 feet high.

Pinus ponderosa Dougl. var. *Jeffreyi* Vasey, Rept. U. S. Comm. Agric. 1875, 179. Black Pine

Throughout the Transition forest, much less abundant than the species and usually found in flats or near the borders of meadows. A smaller tree, 50–75 feet high.

Pinus tuberculata Gordon, Journ. Hort. Soc. **4**: 218, t. Dwarf Pine

Forming a belt nearly half a mile wide, on the arid southern face of the mountains between City and East Twin Creeks, at 3500 feet altitude, in the Upper Chaparral Zone. The southern limit of the species, and its only known occurrence in southern California. Arborescent in habit, but only 5–15 feet high.

Pseudotsuga macrocarpa Mayr, Wald. Nordam. 278. Hemlock
Abundant on the sides of cañons in the Upper Chaparral Zone. There are also a few trees on the north side of the mountains near Gold Mountain. A large tree, 75–90 feet high.

Abies concolor Lindl. & Gord. Journ. Hort. Soc. **5**: 210. White Fir
Scattered throughout the coniferous forest, preferring moister soils, and attaining its best development in the Upper Transition and the lower part of the Canadian Zone. A noble tree, 100–150 feet high.

CUPRESSACEAE

Libocedrus decurrens Torr. Pl. Frem. 7, t. 3. Mountain Cedar
Scattered throughout the coniferous forest of the Transition Zone, mostly in the moister soils of flats and ravines. A thick-based tree, 75–100 feet high.

Juniperus californicus Carr. Rev. Hort. IV. **3**: 166. Desert Juniper
Occasional in dry soil in the Lower Chaparral and Lower Piñon Zones. A large shrub, but arborescent on the Mojave Desert.

Juniperus occidentalis Hook. Fl. Bor. Am. **2**: 166. Mountain Juniper
Abundant on the lower slopes and dry flats of Bear and Holcomb Valleys. An irregular tree, 20–50 feet high.

GNETACEAE

Ephedra viridis Coville, Contr. Nat. Herb. **4**: 220.
A species of the Mojave Desert, ascending the Piñon Zone to Doble and Rose Mine.

SPARGANIACEAE

Sparganium angustifolium Michx. Fl. Bor. Am. **2**: 189.
In pools, Bluff Lake, in the Canadian Zone.

NAJADACEAE

Potamogeton natans Linn. Sp. Pl. 126.
Abundant, floating in ponds, and now in the reservoir, Bear Valley, in the Upper Transition Zone.

Potamogeton pectinatus Linn. Sp. Pl. 127.
Frequent in shallow pools, Bear Valley.

JUNCAGINACEAE

Triglochin maritima Linn. Sp. Pl. 338.
Frequent in marshes, Bear Valley.

ALISMACEAE

Sagittaria arifolia Nutt.; J. G. Smith, Rept. Mo. Bot. Gard. **6**: 32, t. 1.
Emergent in pools, Bluff Lake.

GRAMINEAE

Andropogon macrourus Michx. Fl. Bor. Am. **1**: 56.

In wet muck, Arrowhead Hot Springs, lower border of the Lower Chaparral Zone.

Panicum huachucae Ashe, Journ. Elisha Mitchell Soc. **15**: 51.

San Bernardino Mountains, *Abrams 2737*, acc. Hitchc. in Jeps. Fl. Cal.

Panicum pacificum Hitchc. & Chase, Contr. Nat. Herb. **15**: 229, t. 241.

Frequent in damp soil in the Lower Chaparral Zone.

Aristida fendleriana Steud. Syn. Pl. Glum. **1**: 420.

Infrequent in the Piñon Zone. Cactus Flat; Rose Mine.

Stipa coronata Thurb. in Wats. Bot. Cal. **2**: 287.

Frequent on dry hillsides in the Lower Chaparral Zone.

Stipa Elmeri Piper & Brodie, U. S. Dept. Agr. Div. Agrost. Bull. **11**: 46.

On dry flats at Mill Creek Falls, Upper Transition Zone.

Stipa eminens Cav. Ic. Pl. **5**: 42, t. 467, f. 1.

Frequent on dry hillsides in the Lower Chaparral Zone.

Stipa Lettermani Vasey, Bull. Torr. Club **13**: 53.

On dry hillsides and flats, Bear Valley.

Stipa Parishii Vasey, Bot. Gaz. **7**: 53.

Occasional on dry hillsides in the Upper Transition and Upper Piñon Zones. Mill Creek Falls is the type station.

Stipa speciosa Trin. & Rupr. Mem. Acad. Petersb. VI. Sci. Nat. $\mathbf{5}^1$: 45.

Occasional on dry hillsides on the borders of the Lower Piñon Zone.

Oryzopsis hymenoides Ricker; Piper, Contr. Nat. Herb. 11: 109. Sand Grass.

Rare on dry hills at the upper end of Bear Valley, ascending from the desert where it is abundant.

Muhlenbergia californica Vasey, Bull. Torr. Club. **13**: 53.

Locally abundant on the stony borders of Cold Creek in the Lower Chaparral Zone.

Muhlenbergia filiformis Rydb. Bull. Torr. Club **32**: 600.

Infrequent in dry soil from Talmadge's Meadow in the Lower Transition Zone to the summit of San Gorgonio Mountain.

Muhlenbergia microsperma Trin. Gram. Unifl. 193.

On a dry sand bank at Waterman's Hot Springs, Lower Chaparral Zone.

Alopecurus aristulatus Mich. Fl. Bor. Am. **1**: 43.

Frequent in wet meadows, Bear Valley.

Sporobolus asperifolius Nees & Meyen, Acta Acad. Leop. Circ. **19**: 141.

Bear Valley, acc. Abrams' Flora Los Angeles.

Agrostis exarata Trin. Gram. Unifl. 207.

Occasional on dry hills, Bear Valley.

Agrostis idahoensis Nash, Bull. Torr. Club **24**: 42.

Infrequent in the Upper Transition Zone. Bear Valley; Mill Creek Cañon.

Agrostis schiedeana Trin. Mem. Acad. Petersb. VI. Sci. Nat. 4^1: 327.

In wet meadows, Bear Valley.

Agrostis stolonifera Linn. Sp. Pl. 62.

Occasional in wet sand in the Lower Chaparral Zone. European.

Deschampsis danthonioides Munro; Benth. Pl. Hartw. 342.
Abundant in open forest in the Transition Zone.

Deschampsia caespitosa Beauv. Ess. Agrost. 91, t. 18, f. 3.
In wet meadows, Bear Valley.

Trisetum spicatum Richter, Pl. Europ. **1**: 49.
Occasional in dry soil in the Lower Transition Zone.

Koeleria cristata Pers. Syn. Pl. **1**: 97.
Frequent on dry cañon sides in the Upper Chaparral Zone.

Avena fatua Linn. Sp. Pl. 80.
Occasional in the Lower Chaparral Zone. European.

Danthonia americana Scrib. U. S. Dept. Agr. Div. Agrost. Circ. **30**: 5.
Infrequent in Bear Valley.

Bouteloua gracilis Lag.; Steud. Nom. Bot. ed. 2, **1**: 219.
Infrequent in the Upper Transition Zone. Santa Ana Cañon, *Hall;* Bear Valley.

Melica imperfecta Trin. Mem. Acad. Petersb. VI. Sci. Nat. **2**^{1}: 59.
Abundant on cañon sides in the Chaparral Zone.

Melica imperfecta Trin. var. *minor* Scrib. Proc. Acad. Philad. 1885, 42.
On bushy hillsides at the head of Edgar Cañon (type), Upper Chaparral Zone.

Melica imperfecta Trin. var. *refracta* Thurb. in Wats. Bot. Cal. **2**: 303.
Summit of Waterman Cañon, in the Upper Chaparral Zone.

Melica stricta Bolander, Proc. Cal. Acad. **3**: 4.
Occasional on dry ridges in the Upper Transition Zone. Bear Valley.

Lamarkia aurea Moench, Meth. Pl. 201.
Occasional in the Lower Chaparral Zone. European.

Poa atropurpurea Scribn. U. S. Dept. Agr. Div. Agrost. Bull. **11**: 53, t. 10.
Locally abundant on dry hillsides, Bear Valley, the type station.

Poa fendleriana Vasey, U. S. Dept. Agr. Div. Agrost. Bull. **13**^{2}: t. 74.
Rose Mine, Upper Piñon Zone.

Poa longiligua Scribn. & Williams, U. S. Dept. Agr. Div. Agrost. Circ. **9**: 3.
Hillsides at Mill Creek Falls, Upper Transition Zone.

Poa nevadensis Vasey; Scribn. Bull. Torr. Club. **10**: 66.
Hillsides at Bear Valley.

Poa pratensis Linn. Sp. Pl. 67. Bluegrass
In meadows, Bear Valley; evidently native.

Poa scabrella Benth.; Vasey, Grasses U. S. 42.
Occasional on cañon sides in the Lower Chaparral Zone.

Glyceria elata Hitchc. in Jeps. Fl. Cal. 162.
Infrequent on the wet margins of streams in the Lower Transition Zone.

Puccinellia nuttalliana Hitchc. in Jeps. Fl. Cal. 162.
In subalkaline soil, Bear Valley.

Festuca eriolepis Desv. in Gay, Fl. Chil. **6**: 428.
On dry slopes in the Chaparral Zone.

Festuca megaleura Nutt. Journ. Acad. Philad. II, **1**: 188.
Frequent on dry slopes in the Lower Chaparral Zone.

Festuca microstachys Nutt. Journ. Acad. Philad. II, **1**: 187.
Frequent on dry slopes in the Chaparral and Transition Zones.

Festuce Myurus Linn. Sp. Pl. 74.

Frequent in dry soil in the Lower Chaparral Zone.

Festuca octoflora Walt. Fl. Carol. 81.

Frequent in dry soil in the Lower Chaparral Zone.

Festuca pacifica Piper, Contr. Nat. Herb. **10**: 12.

Occasional on dry slopes in the Lower Chaparral Zone.

Festuca Parishii Hitchc. in Jeps. Fl. Cal. 169.

Occasional on bushy slopes in the Upper Chaparral Zone. Mill Creek is the type station.

Festuca supina Schur. Enum. Pl. Transs. 784.

San Gorgonio Mountain, *Reed, Hall,* acc. Hitchc. in Jeps. Fl. Cal.

Bromus arenarius Labill Nov. Holl. Pl. **1**: 23.

Abundantly naturalized about Pine Flat, Waterman Cañon. Upper Chaparral Zone. Australian.

Bromus carinatus H. & A. var. *Californicus* Shear, U. S. Dept. Agr. Div. Agrost. Bull. 23, 60.

Occasional in the Lower Chaparral Zone. Cañon Diablo.

Bromus grandis Hitchc. in Jeps. Fl. Cal. 175.

Locally abundant on rocky hillsides at the mouth of Snow Cañon.

Bromus hordaceus Linn. Sp. Pl. 77.

Occasional in the Lower Chaparral Zone. European.

Bromus marginatus Nees; Steud. Syn. Pl. Glum. **1**: 322.

On hillsides near the mouth of Snow Cañon in the Upper Transition Zone.

Bromus orcuttianus Vasey var. *Hallii* Hitchc. in Jeps. Fl. Cal. 175.

San Bernardino Mountains, *Mrs. Wilder* acc. Hitchc. *l.c.*

Bromus rubens Linn. Cent. Pl. **1**: 5.

Often abundant on dry slopes in the Lower Chaparral Zone. European.

Bromus subvelutinus Shear, U. S. Dept. Agr. Div. Agrost. Bull. **23**: 52.

San Bernardino Mountains, *Hall,* acc. Hitchc. in Jeps. Fl. Cal.

Bromus villosus Forsk. var. *Gussonei* Aschers. & Graebn. Syn. Mitteleur. Fl. **2**: 595. Broncho Grass

Often abundant in the Lower Chaparral Zone. European.

Bromus vulgaris Shear, U. S. Dept. Agr. Div. Agrost. Bull. **23**: 43.

San Bernardino Mountains, *Abrams,* acc. Hitchc. in Jeps. Fl. Cal.

Agropyron Parishii Scribn. & Smith, U. S. Dept. Agr. Div. Agrost. Bull. **4**: 28.

Locally abundant on stony hillsides, Waterman Cañon, at 3000 ft. alt. The type station.

Hordeum jubatum Linn. Sp. Pl. 85.

Occasional in dry soil in the Transition Zone.

Hordeum murinum Linn. Sp. Pl. 85.

Occasional in the Lower Chaparral Zone. European.

Hordeum nodosum Linn. Sp. Pl. ed. 2, **1**: 126.

Abundantly naturalized in the Chaparral and Transition Zones. European

Elymus glaucus Buckl. Proc. Acad. Philad. 1862: 99.

Frequent in the Chaparral and Transition Zones.

Elymus glaucus Buckl. var. *Jepsoni* Davy in Jeps. Fl. W. Mid. Cal. 79.

Deep creek, in the Lower Transition Zone, *Abrams,* acc. Hitchc. in Jeps. Fl. Cal.

Sitanion jubatum J. G. Smith, U. S. Dept. Agr. Div. Agrost. Bull. **18**: 10.
Occasional in dry soil, Bear Valley.

Sitanion californicum J. G. Smith, U. S. Dept. Agr. Div. Agrost. Bull. **18**: 13.
Infrequent in the Upper Transition Zone. Mill Creek; Bear Valley.

Sitanion minus J. G. Smith, U. S. Dept. Agr. Div. Agrost. Bull. **18**: 12.
Summit of San Gorgonio Mountain, *Mrs. Wilder*.

CYPERACEAE

Cyperus aristatus Rottb. Descr. Nov. Pl. 22.
In wet sand, Waterman Hot Springs, in the Lower Chaparral Zone.

Cyperus Parishii Britton in Parish, Bull. S. Cal. Acad. **3**: 52.
In a wet meadow, Head of Edgar Cañon, in the Upper Chaparral Zone.

Schoenus nigricans Linn. Sp. Pl. **1**: 43.
On wet banks, Arrowhead Hot Springs.

Eleocharis montana R. & S. Syst. **2**: 154.
On wet banks, Arrowhead Hot Springs.

Fimbristylis thermalis Wats. King's Expl. **5**: 350.
In soil moistened by warm water, Arrowhead and Waterman Hot Springs.

Scirpus microcarpus Presl. Rel. Haenk. **1**: 195.
Common along streams in the Lower Chaparral Zone.

Scirpus pauciflorus Lightf. Fl. Scot. 1078.
Rare; dry meadow, Bear Valley, in the Upper Transition Zone.

Carex (*Primocarex*) *exserta* Mack. ined.
Rare; on a dry, stony hillside, Bear Valley.

Carex (*Primocarex*) *multicaulis* Bailey, Bot. Gaz. **9**: 117.
Frequent on dry hillsides, in pine forest, throughout the Lower Transition Zone.

Carex (*Vignea*) *Abramsii* Mack. Bull. Torr. Club **36**: 482.
In a marsh between Bear Valley and Bluff Lake (type), and on Deep Creek, *Abrams*, in the Transition Zone, and on High Creek, *Grant*, in the Canadian Zone.

Carex (*Vignea*) *abrupta* Mack. ined.
High Creek, *Grant*, and Bluff Lake, *Mrs. H. E. Benton*, in the Canadian Zone.

Carex (*Vignea*) *albomarginata* Mack. ined.
Summit of San Gorgonio Mountain, *Mrs. C. M. Wilder*, in the Alpine Zone. Also on the summit of San Jacinto Mountain, and distributed from both stations as *C. Preslii* Steud.

Carex (*Vignea*) *alma* Bailey, Mem. Torr. Club **1**: 50.
Frequent on stony stream banks in the Chaparral and Lower Transition Zones and rare in the Piñon.

Carex (*Vignea*) *athrostachya* Gray, Proc. Am. Acad. **7**: 393.
Frequent in meadows, Bear Valley.

Carex (*Vignea*) *Bolanderi* Olney; Gray, Proc. Am. Acad. **7**: 393.
In marshes, Mill Creek Falls and Head of Waterman Cañon.

Carex (*Vignea*) *festiva* Dewey, Am. Journ. Sci. **29**: 246.
In wet meadows, Bear Valley.

Carex (*Vignea*) *feta* Bailey, Bull. Torr. Club. **20**: 417.
In a cienega, Waterman Cañon, in the Lower Chaparral Zone.

Carex (*Vignea*) *Jonesii* Bailey, Mem. Torr. Bot. Club. **1**: 16.
In a meadow, Bluff Lake, in the Canadian Zone.

Carex (*Vignea*) *multicostata* Mack. ined.
In a meadow, Bear Valley Dam, *Parish 1306*, type.

Carex (*Vignea*) *specifica* Bailey, Mem. Torr. Club **1**: 21.
Frequent in dry soil in the Transition Zone.

Carex (*Vignea*) *stellulata* Good. var. *ormantha* Fernald, Rhod. **3**: 222.
Locally abundant in a wet meadow, Bluff Lake.

Carex (*Vignea*) *subfusca* W. Boott in Wats. Bot. Cal. **2**: 234.
In a wet meadow, Bear Valley.

Carex (*Eucarex*) *aurea* Nutt. var. *celsa* Bailey, Mem. Torr. Club **1**: 75. *C. Hassei* Bailey, Bot. Gaz. **21**: 5.
In a meadow at Seven Oaks, in the Transition Zone. More abundant in the Cismontane Valleys.

Carex (*Eucaryx*) *laciniata* Boott in Benth. Pl. Hartw. **3**: 341.
Locally abundant along a dry stream bed, Waterman Cañon, in the Lower Chaparral Zone.

Carex (*Eucaryx*) *lanuginosa* Michx. Fl. Bor. Am. **2**: 175.
In a marsh, Edgar Cañon, in the Lower Chaparral Zone. More abundant at lower altitudes.

Carex (*Eucarex*) *nebraskensis* Dewey, Am. Journ. Sci. **2**: 107.
Occasional on stream banks in the Transition Zone.

Carex (*Eucarex*) *Parishii* Mack. ined.
Bear Valley, in the Upper Transition Zone and Waterman Cañon in the Lower Chaparral Zone.

Carex (*Eucarex*) *quadrifida* var. *cacca* Bailey, Bot. Gaz. **21**: 8.
In meadows in the Upper Transition, Canadian and Hudsonian Zones.

Carex (*Eucarex*) *Schottii* Dewey, Bot. Mex. Bound. 231.
In swamps, Bear Valley. More abundant in San Bernardino Valley.

Carex (*Eucarex*) *senta* Boott, Ill. **4**: 174.
Frequent in meadows in the Upper Transition Zone.

Carex (*Eucarex*) *triquetra* Boott, Trans. Linn. Soc. **20**: 126.
Frequent on dry bushy hillsides in the Lower Chaparral Zone.

Carex (*Eucarex*) *utriculata* Boott in Hook. Fl. Bor. Am. **2**: 221.
Frequent in very wet meadows, Bear Valley.

Carex (*Eucaryx*) *utriculata* var. *minor* Boott in Hook. Fl. Bor. Am. **2**: 221.
With the species.

LEMNACEAE

Lemna minima Phil. Linnaea **33**: 239.
Bear Valley, acc. Abrams Fl. Los Ang.

Lemna trisulca Linn. Sp. Pl. 971.
Bear Valley, acc. Abrams, Fl. Los Ang.

JUNCACEAE

Luzula comosa E. Mey. Synop. Luzul. 21.
Frequent in damp soil in the Transition Zone.

Luzula comosa E. Mey. var. *macrantha* Wats. Bot. Cal. **2**: 203.
Growing with the species, but less abundant.

Juncus balticus Willd. Berlin. Mag. **3**: 298.
Big. Meadows, *Hall*. Bear Valley. Mill Creek.

Juncus bufonius Linn. Sp. Pl. 328.
In wet sand, Bear Valley and Bluff Lake.

Juncus canaliculatus Engelm. Bot. Gaz. **7**: 6.
In moderately damp soil in the Chaparral, Transition and Piñon Zones. The type was from Mill Creek Cañon.

Juncus effusus Linn. var. *pacificus* Fern. & Weig. Rhodora **12**: 89.
In damp soil in the Lower Transition Zone.

Juncus interior Weigand, Bull. Torr. Club, **27**: 516.
In meadows in the Lower Transition Zone.

Juncus latifolius Buchen. Monog. Junc. 425.
Caespitose in wet meadows and on stream banks in the Upper Transition Zone.

Juncus mertensianus Bong. Mem. Acad. St. Petersb. VI. Sci. Nat. **2**: 167.
In a marsh at 6000 ft. alt., Mill Creek Cañon.

Juncus nevadensis Wats. Proc. Am. Acad. **14**: 303.
Common in meadows in the Transition Zone.

Juncus obtusatus Engelm. Trans. St. Louis Acad. **2**: 495.
In meadows in the Lower Transition Zone.

Juncus oxymeris Engelm. Trans. St. Louis Acad. **2**: 483.
Occasional in the Transition Zone.

Juncus Parryi Engelm. Trans. St. Louis Acad. **2**: 447.
Summit of San Gorgonio Mountain, *Mrs. Wilder*.

Juncus phaeocephalus var. *paniculatus* Engelm. Trans. St. Louis Acad. **2**: 484.
Occasional by streams in the Chaparral and Transition and Canadian Zones up to 8200 ft. alt.

Juncus textilis Buchen. Abh. Nat. Ver. Brem. **17**: 336.
Waterman Cañon, in the Lower Chaparral Zone.

Juncus triformis var. *uniflorus* Engelm. Trans. St. Louis Acad. **2**: 493.
On wet sandbars, Bear Valley.

Juncus xiphioides E. Mey. Synop. Junc. 50.
Borders of streams and marshes in the Transition and Piñon Zones.

(To be continued)

REDWOODS, RAINFALL AND FOG

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The distribution of the redwood of California (*Sequoia sempervirens* Endl.) has been commonly related to the summer fogs so characteristic of the coast of that state. It is certain that other influences have a share, notably rainfall; but no investigations using other than merely observational methods have been made bearing upon the relative importance of these and other factors. The following study, though somewhat crude in method, yielded fairly exact results as to the rainfall factor, and seems to offer useful evidence bearing upon the problem. The work was done during the rainy seasons of 1913–1914 and 1914–1915, in the Santa Cruz Mountains, Stanford University being used as a base of operations. My thanks are due to each member of the staff of the Department of Botany of Stanford University for assistance in many ways.

The Santa Cruz Mountains trend northwest and southeast, approximately parallel to the coast. East of them lie the southern extension of San Francisco Bay and the Santa Clara Valley, and west of them is the Pacific Ocean. Southward they are a complex mass 30 km. in maximum breadth, deeply cut by abrupt valleys and cañons. Northward they gradually narrow, and opposite Palo Alto and Redwood City they have more of the character of a single ridge with projecting spurs, the longer ones pointing westward. Still farther north they are again complex, but lower, and they finally die out in the hills south of San Francisco. The east face of the mountain mass, being a fault scarp, is nearly everywhere abrupt, and the highest points of the range, such as Black Mountain (847 m.), Castle Rock Ridge (912 m.), and Loma Prieta Mountain (912 m. +) are near the eastern margin.

In the main body of the range redwood forest is the prevailing vegetation type. This great forest mass extends from near Santa Cruz northward, covering the ridges and valleys of the central part of the range with fair solidity as far as Butano Ridge. North of this its extent is more limited and its continuity somewhat broken, the south facing slopes and ridge tops being clothed instead with chaparral or grassland vegetation. At a point on the main ridge directly west of Palo Alto the redwood forest ends, chaparral, oak forest, and meadow sharing the region northward.

Obviously the main factor in the distribution of the redwood is water in some form or other. In the Santa Clara Valley the supply is hopelessly inadequate except along the banks of the permanent streams. The same is true in a less extreme degree of the two foothill regions and the coast. Turning to the mountain region proper, a puzzling fact appears. Certain areas, apparently not differing in topography and soil from nearby ones which support luxuriant redwood forest, are practically without these trees. The mass comprising Black Mountain and Monte Bello Ridge is a conspicuous example. Even in the deep cañons such as that of Stevens Creek, which surround and penetrate the mass, redwoods are almost absent. The same is true of the mountains and cañons of the northeast face of the range, southeastward from Black Mountain. These slopes and valleys are farthest from the Pacific, and therefore a very natural hypothesis to explain the absence of redwoods here is that it is due to insufficient rainfall—quite certainly an adequate cause in the case of the Santa Clara Valley and in the foothills. The localities were conveniently situated, and therefore I attempted to solve the problem by comparing the precipitation in nearby areas, similar in topography and soil, some bearing luxuriant redwood forest, some with none at all.

Observations were not confined to the mountain region itself. Rain gauges of a type shortly to be described were set out in a group of stations, beginning at Palo Alto in the Santa Clara Valley, and extending westward and southwestward across the Santa Cruz Mountains to the ocean shore. I have arranged the table of results under five regional heads, from east to west; Santa Clara Valley, Eastern Foothills, Santa Cruz Mountains, Western Foothills, Coast. The stations are numbered in table 1, and the map indicates their locations.

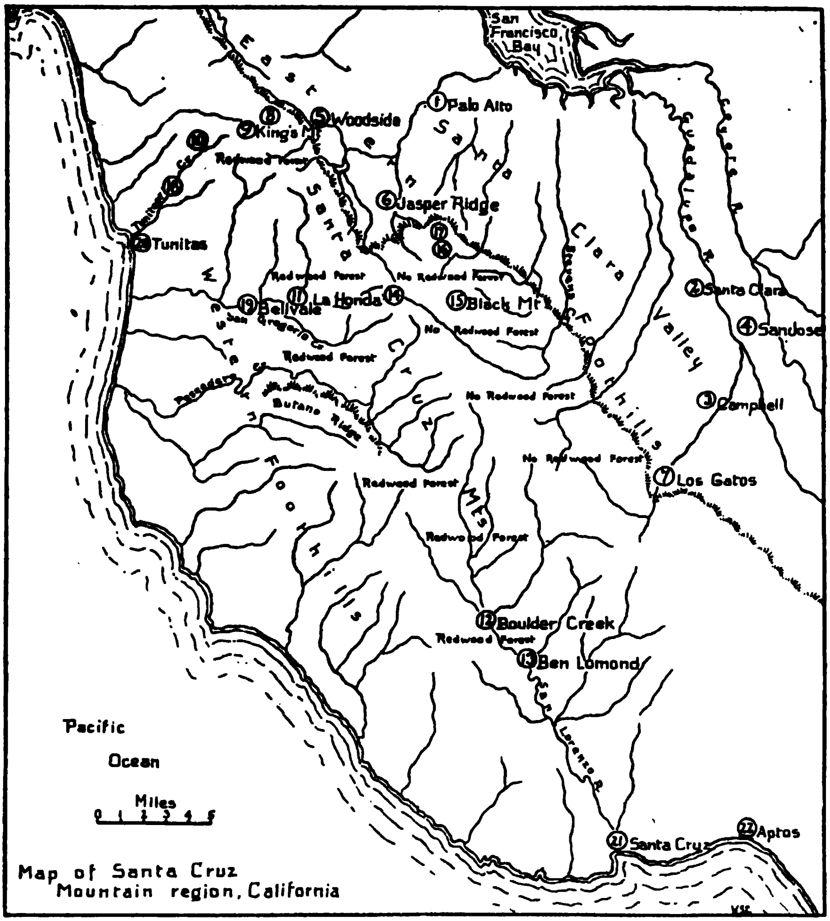

Fig. 1

The mountains themselves have been already described. The other divisions are as follows:

The northwestern end of the Santa Clara Valley (Sta. 1–4) is at present largely under cultivation, but was formerly covered by grassland, chaparral, and open oak forest (*Quercus agrifolia* Née and *Q. lobata* Née). The altitudes are negligible. The eastern foothill region (Sta. 5–7), several kilometers wide west of Palo Alto, narrows almost to extinction southeastward, the mountains fronting abruptly upon the valley. The altitudes of stations occupied range from 120 m. to 250 m. The vegetation consists dominantly of chaparral of several types, with oak forest (*Quercus agrifolia* most important) in ravines and on steep north slopes. Close to the main mountain front a few redwoods occur beside streams. The western foothills are indefinite in extent, merging gradually with the higher mountains to the east. The stations occupied, both of which are in valleys, were 97 m. and 106 m. in altitude. The hills are mainly grassy, with little chaparral and few oaks. Tongues of redwood extend down the cañons toward the ocean. The coast in part is bordered by a flat strip 2 km. wide or less; in other places the hills come to the ocean, and steep slopes and sea cliffs occur. The coast station at Tunitas was at the top of one of these cliffs, 70 m. above tide. The vegetation of the seaward facing slopes is the characteristic coastal scrub, including *Baccharis pilularis* DC, *Rhamnus californica* Esch., *Rhus diversiloba* T. & G., and *Lupinus arboreus* Sims.

While interested in the problem of the redwood, my attention was called by Dr. Forrest Shreve to a simple means for measuring total precipitation for long periods, which is in use among the ranchers in the vicinity of Tucson, Arizona, and which was used by Dr. Shreve in his studies in the Santa Catalina Mountains. This device seems to have sufficient possibilities for usefulness to merit a full description. I wish also to suggest some modifications which seem to me to be improvements. The instrument consists essentially of a container of convenient size fitted with a tin funnel to receive the rain. A little kerosene, put into the container, floats upon the surface of the water and prevents loss by evaporation. The precipitation is determined by pouring the contents into a graduate. The amount of the kerosene is deducted and the volume of water is divided by the receiving area of the funnel.

After some experimentation I developed the following as the most convenient form for the apparatus. For the container I used a 2 gallon galvanized iron kerosene can, with a screw top 3 or 4 cm. in diameter and a spout with a screw cap. This container, fitted with the funnel as described, was found sufficient to accommodate safely 225 cm. of precipitation. The can was painted black to reduce its visibility; notwithstanding which, the inevitable small boy found and appropriated several. The funnel was of the ordinary tin kitchen variety, the receiving end being about 6 cm. in diameter. To minimize splashing I added a vertical tin collar 2.5 cm. high, and a circle of coarse wire netting was placed within to prevent clogging by debris. The funnel was fitted to a hole in a cork stopper which in turn fitted the opening in the top of the container. All joints were made waterproof, and the top of the funnel was accurately levelled after the apparatus was put in place. That these precautions are necessary is shown by the following table:

Standardization of four instruments

	I	II	III	IV
Before waterproofing and levelling	1.00	0.67	0.83	0.88
After waterproofing and levelling	1.00	0.92	0.92	0.94

Three further tests confirmed the approach to uniformity indicated above. As a precaution, a small bent glass tube with down pointing outer end was run through the cork beside the funnel as an outlet for air. It was thought that an exceptionally heavy rain might so fill the tube of the funnel that no air could escape through it, thus causing temporary overflow. I have no means of knowing whether this is a necessary safeguard. The funnels were numbered and the receiving area of each was computed from the average of three diameters. Figure one shows one of the instruments in position.

Twelve instruments were set out October 18, 1913, and taken in May 13, 1914. Complete records were obtained from seven, and approximate records from four others which had disappeared between the midwinter reading in January and the final one. These were computed by adding to the partial record an amount proportional to the average amount received during the second half of the season by those from which complete records were obtained. On October 27 and 31, 1914, gauges were set out at practically the same series of stations as the year before, and at a number of additional ones, including the summit of Black Mountain and the hamlet of Bellvale. These were taken in June 28 and July 28, 1915. Several others, placed at various strategic points, disappeared during the winter. In the table I have added figures from the United States Weather Bureau reports, obtained during the same two seasons at nine stations which are useful in supplementing the results personally secured.

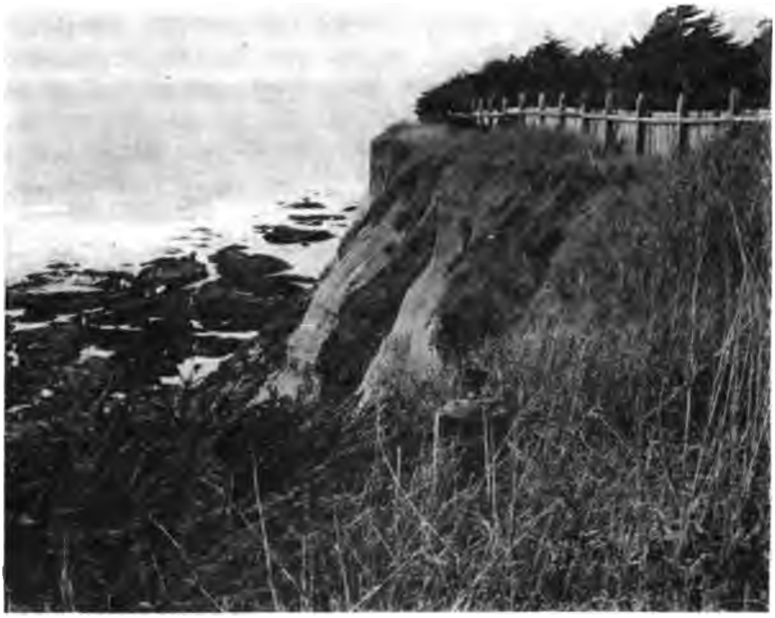

Fig. 2. Rain gauge in place at top of coastal bluff

From table 1, in which the results of the rainfall observations are summarized, the following conclusions have been drawn.

TABLE 1

Precipitation in the Santa Cruz Mountain region

STATION	SANTA CLARA VALLEY				EASTERN FOOTHILLS			SANTA CRUZ MOUNTAINS										WESTERN FOOTHILLS		COAST		
								Redwood forest						No redwood forest								
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
	*Palo Alto	*Santa Clara	*Campbell	*San Jose	Woodside	Jasper Ridge	*Los Gatos	King's Mt. Road	King's Mt. Summit	Ridge at head of Tunitas Creek	La Honda	*Boulder Creek	*Ben Lomond	Alpine and Page Mill Crossroads	Black Mt. Summit	391 m. Summit east of Page Mill Road	Page Mill and Hidden Villa Crossroads	First Redwoods in Tunitas Cr. Valley	Bellvale	Tunitas	*Santa Cruz	*Aptos
Altitude (m.)......	17	27	66	29	122	249	182	410	623	497	122	147	105	669	847	391	304	106	97	70	6	31
Precipitation (cm.) 1913–14...........	62.15	48.95	50.01	47.83	129.61	103.71	134.06	169.25	172.39	A 97.00	A 134.90	171.12	197.66	155.42		A 173.25	A 186.94	87.11		131.94	87.45	94.84
Precipitation 1914–15...........	66.40	68.58	55.70	57.68	81.39		93.50	126.29	139.32	116.51	103.35	171.37	161.95	146.29	122.50	148.67		83.36	37.19	75.29	107.31	93.09
Regional average 1913–14...........	52.24				122.46			157.05						171.87				87.11		104.74		
Regional average 1914–15...........	62.09				87.44			136.53						139.15				60.27		91.90		

* Data from reports of United States Weather Bureau.
A—Approximate.

First of all, we have striking instances of the great difference in precipitation which frequently occurs in California in stations only a few kilometers apart. The greatest distance between any two places listed here is 54 km. The series from Palo Alto to Tunitas is especially interesting. In 1914–1915 the figures for five stations along this line, one in each physiographic province, were as given in table 1. It should be mentioned that the two winters studied were seasons of more than average rainfall. The mean annual precipitation for Palo Alto is about 40 cm.

It is also indicated that altitude is the main factor influencing the amount of precipitation. The immediate vicinity of the coast is relatively deficient as well as the interior valley.

TABLE 2

STATION	REGION	DISTANCE FROM PALO ALTO	ALTITUDE	RAINFALL
		km.	*m*	*cm.*
Palo Alto	Valley		17	66.48
Woodside	E. foothills	9.6	122	81.39
King's Mt	Mountains	14.4	623	139.32
Tunitas Creek	W. foothills	17.6	106	83.36
Tunitas	Coast	24.0	70	75.29

Further, returning to the hypothesis suggested on a previous page, that difference in rainfall is responsible for the presence of redwood forest in certain areas in the mountains and its absence in others, we gather from the table the following evidence. In both groups of rainfall stations—those with and those without redwood forest—precipitation is abundant. In fact, the stations without redwood forest are consistently a little more rainy than those possessing it. Our hypothesis therefore is unsupported; rainfall difference is not here the deciding factor; and high precipitation alone is not sufficient to make possible the development of redwood forest covering mountain slopes away from streams.

The explanation for the last statement is found in the long dry season characteristic of the California climate. During this critical period the soil everywhere away from permanent streams becomes very dry, in relatively mesophytic as well as in xerophytic habitats. I have demonstrated this in unpublished work dealing with the ecology of the chaparral. Soil moisture determinations made in the eastern foothill region on opposite north and south facing slopes dominated respectively by chaparral (xerophytic) and oak forest (mesophytic) show that the water contents of the two habitats, differing greatly during the rainy season, become almost equally deficient by the end of the dry, 1.4% being the minimum for the chaparral and 3% for the oak forest (average of three depths). The redwood soil in the mountains would doubtless show the same severe depletion, though probably to a somewhat less degree. The evaporation rate too is very high at the critical period. In the week ending September 19, 1913, at the same foothill station, it reached the maximum for the year of 51 cc. loss per day from the porous cup atmometer.

The redwood is unusually sensitive to the danger of rapid water loss, even when the soil water supply is ample. This is shown by the following instance. Early in May, 1915, a terrific north wind swept over central California, so desiccating in its effects that roses were turned to paper and gardens showed the effects for weeks afterward. A few days later I crossed the Santa Cruz Mountains and found on the north facing slopes every redwood brown as if scorched by fire. Trees growing in ravines but projecting above the ridge top were green below and brown above. Frequently trees of redwood and douglas fir were seen side by side, equally exposed. Invariably the redwood was brown and the douglas fir unharmed. In this connection it is of interest to note that in the mountain areas where redwood is practically absent, douglas fir is abundant.

It is thus shown conclusively that even in certain mountain areas which have ample winter precipitation, redwood is excluded from all places except the immediate vicinity of streams because of desiccation of the soil during the rainless season accompanied by high evaporation rate. This state of affairs might be improved by the lowering of the evaporation rate, resulting in conservation of the limited supply of available water; and the ocean fogs, which cover parts of the mountains on a large majority of summer days, do this effectively, as has been pointed out by several writers. Fogs also add a certain amount to the soil water supply, as Cannon has noted.[1] The ground under a redwood tree during a fog is often decidedly wet, but whether this water is abundant enough or penetrates deeply enough to be of much consequence is doubtful. At any rate the decrease of evaporation is of very great importance.

Light might be thrown upon the problem if data could be obtained concerning the extent of the region which is ordinarily covered by the fog blanket. I can give here some general observations which are helpful. From Palo Alto the east face of the Santa Cruz Mountains, extending from a point about west of Redwood City southeastward to the mass of Black Mountain, is in full view. The northwestern half is clothed with redwoods; the Black Mountain mass has none. On a majority of days during the summer a fog blanket may be seen covering the northwestern end of the range, sometimes of greater, sometimes of less extent, but centering in the region of King's Mountain, where the redwood forest is heaviest. Frequently it pours over the edge and descends the eastern slope. Redwoods are frequent upon this slope and are not entirely confined to the immediate vicinity of streams. Less frequently the fog is seen to spread southward along the summit ridge, but very rarely indeed does it reach Black Mountain. The explanation probably is that in the region of King's Mountain the range is relatively narrow and the fog attains the eastern slopes; west of Black Mountain the mountain region is much broader, and the fog blanket, if of the same dimensions as farther north, stops short of the eastern edge of the mountains, possibly near Butano Ridge. The fog-frequented area around King's Mountain includes the four stations which I established in the redwood forest region; the fogless area of Black Mountain and its environs includes all of my four stations located in country devoid of redwood forest; and the latter region has slightly the higher rainfall of the two. It is therefore apparent that the first condition necessary for redwood forest is an ample supply of soil water; but that this alone is not sufficient. The second, a summer fog blanket, cutting down the rate of evaporation, is just as essential. The results may be expressed in tabular form (table 2).

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[1] Cannon, W. A. On the relation of redwoods and fog to the general precipitation in the redwood belt of California. Torreya 1: 137–139. 1901.

TABLE 3

	VALLEY	E. FOOTHILLS	MOUNTAINS		W. FOOTHILLS	COAST
Rainfall	Deficient	Deficient	Ample	Ample	Deficient	Deficient
Ocean fog	None	Occasional	Abundant	Occasional	Abundant	Abundant
Redwoods	None except occasional along streams	Occasional along streams	Luxuriant forest	Occasional along streams	Along streams	None

SUMMARY

The redwood requires a high ratio of water supply to water loss, and is unusually sensitive to the danger of rapid transpiration, even when the supply is ample.

Soil moisture studies in the Palo Alto region indicate that during the rainless season the soil becomes dangerously dry, even in the more mesophytic habitats.

The redwood may exist in regions where the rainfall is deficient, but only close to permanent streams.

For full development of redwood forest, covering mountain slopes which may become relatively dry as well as the immediate environs of permanent streams, heavy winter precipitation is necessary, but alone is not sufficient. Abundant summer fog is also essential, its effects being to decrease the water loss, and in some degree to add to the soil water supply. Where summer fogs do not occur, or where they occur infrequently, no true forest of redwood is possible, even though the rainfall be as high or higher than in fog-frequented areas. In areas of the former kind the infrequent redwoods are confined to the banks of streams, as in regions of deficient precipitation.

For the rainfall studies involved in the above work a simple type of rain gauge, making possible summation of precipitation for long periods, was used, and is described in the body of the paper.

BOOKS AND CURRENT LITERATURE

RECENT WORK ON THE LIFE HISTORIES OF THE KELPS.—Since Drew's announcement[1] that the motile cells of *Laminaria* are actually gametes, and not zoospores, as they were previously considered, there has been a good deal of skepticism as to the accuracy of his observations. Recent papers by Sauvageau[2] and Kylin[3] have cleared the matter up in a most interesting way. To Sauvageau belongs the credit of priority. Kylin's results, however, confirm and add somewhat to the earlier observations.

The facts as given by Kylin may be summarized as follows. On germination, the zoospores give rise in three to five weeks to gametophytes. The male gametophytes are short, monosiphonous, and irregularly branching. They produce antheridia singly as small terminal or lateral cells. The antherozoids have not been observed. The female gametophytes may be similar to the male but with fewer and larger cells, or may consist of a single large cell produced from the swelling germ tube of the germinating zoospore. In either case all cells of the female gametophytes are oogonia, each producing a single egg, which is extruded from a narrowed terminal neck. Fertilization was not observed. The (fertilized) egg develops directly into an unbranched sporophyte (the *Laminaria* plant), which is at first monosiphonous and later becomes a flattened plate. By the end of the first summer the young sporophyte is 2 to 3 dcm. long. Cytological details are entirely lacking. It is to be expected that these will soon be forthcoming.

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[1] Drew, G. H. The Reproduction and Early Development of *Laminaria digitata* and *Laminaria saccharina*. Ann. Bot. **24.** 1910.

[2] Sauvageau, C. Sur la sexualite hétérogamique d'une Laminaire (*Saccorhiza bulbosa*). Sur les débuts du développement d'une Laminaire (*Saccorhiza bulbosa.*) Compt. rend. de l'acad. sci. Paris **161.** 1915.

——— Sur les gametophytes de deux Laminaires (*L. flexicaulis* et *L. Saccharina*). Ibid. **162.** 1916.

——— Sur la sexualité hétérogamique d'une Laminaire (*Alaria esculenta*). Ibid. **162.** 1916.

[3] Kylin, H. Ueber den Generationswechsel bei *Laminaria digitata*. Svensk. bot. Tidskr. **10,** 551–561. 1916.

The establishment of alternation of generations of the type described fills to a certain extent the tremendous gap between the Fucaceae and the Phaeosporales, and clears up the hitherto doubtful homologies of the former. Improbable as it seemed on the face of it, the *Fucus* plant is really a sporophyte homologous with *Laminaria*, while the gametophyte of *Laminaria* corresponds to the cell-generations within the oogonium and antheridium of *Fucus*. The gametophyte of *Laminaria*, though much reduced, is an independent plant, while that of *Fucus* reaches a stage even nearer total suppression than is shown in the typical Angiosperm. It is as remarkable as it is unexpected that the brown algae should show a series parallel to that of the archegoniates, the more so since the evidence at hand indicates an antithetic origin of the sporophyte in the higher plants, while in the brown algae there is good reason to believe that the sporophyte is of homologous origin.

If closer study confirms this interpretation of the facts, the Laminariaceae must be classed with *Fucus* among the Cyclosporales, standing between the Cutleriaceae and the Fucaceae.—I. F. LEWIS.

DICOTYLEDONOUS WOODS.—The interrelationships of the dicotyledons are confessedly a tangle. Since 50% of the families are entirely made up of woody plants, the comparative structure of the wood ought to furnish facts of great value. But it has been found difficult to say what diagnostic features are of phylogenetic value, and only recently a beginning has been made in this direction. All that can be said at present is to "report progress," as is evidenced by papers of Adkinson,[1] Hoar,[2] Jeffrey and Cole,[3] in addition to earlier papers from the same laboratory. Plowman has contributed an illuminating comparison of the box elder with true maples,[4] in which he concludes on anatomical and other grounds that "*Negundo aceroides*" became segregated from *Acer* during the Glacial Period.—M. A. CHRYSLER.

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[1] Adkinson, J. Some Features of the Anatomy of the Vitaceae. Ann. Bot. **27**: 133–139. 1913.

[2] Hoar, C. S. A Comparison of the Stem Anatomy of the Cohort Umbelliflorae. Ann. Bot. **29**: 55–63, pls. 4, 5. 1915.

Ibid. The Anatomy and Phylogenetic Position of the Betulaceae. Amer. Jour. Bot. **3**: 415–435. 1916.

[3] Jeffrey, E. C. and Cole, R. D. Experimental Investigations on the genus *Drimys*. Ann. Bot. **30**: 359–368, pl. 7. 1916.

[4] Plowman, A. B. Is the Box Elder a Maple? Bot. Gaz. **60**: 169–192, pls. 5–10. 1915.

NOTES AND COMMENT

The report of the Office of Forest Investigations of the United States Forest Service for the fiscal year 1916 describes the recent results of the investigative work which has been under way for several years. There has been a slight decrease in reforestation experiments and a greater attention to fire protection and excessive erosion. A study is being made of climatic conditions and the moisture of the forest litter in connection with the danger of fires; and of the influence of vegetation, topography, wind and other factors on the spread of fires. Added to the injury which erosion inflicts upon the forest itself is the further harm that comes from the silting up of reservoirs and irrigation canals, which are usually fed from National Forests. Both remedial and preventive measures are being taken to reduce erosion, particularly by the proper control of grazing. Some very definite results have now been secured for the guidance of work in planting and reforestation. For most trees, and in the majority of localities, planting has been found more successful than direct seeding. It has also been found that seeds produced in a given locality are better for use in that place than seeds imported from elsewhere. All phases of nursery practice, including selection, planting and germination of seeds, treatment of seedlings, and transplanting have now been placed on a thoroughly scientific basis, and it is possible to plant certain well studied trees with assurance of high percentages of survival. The study of the climatic conditions in various forests types is now being pursued at all of the Forest Experiment Stations, receiving the most attention at 12 localities in the central Rocky Mountain region in the vicinity of the Fremont Experiment Station. Atmospheric and soil temperature, soil moisture and precipitation are being observed at all of the stations, and evaporation, wind velocity, and sunshine at some of them. Great interest will attach to the results of this work, from which it will be possible to learn the climatic requirements of some of the leading types of natural vegetation in the western states. The investigations mentioned, and numerous minor ones which are reported, show that the Investigative Office of the Forest Service is engaged in work which combines the greatest practicality and national importance with a high degree of scientific value. Through no other agency will be able to learn so much about the ecology of forest trees and the nature of the conditions in our diversified forest areas.

Mr. C. R. Tillotson has recently prepared a pamphlet on Nursery Practice on the National Forests (Department of Agriculture, Bull. No. 479), which contains a very full account of the methods by which seedling trees are produced, cared for, and transplanted in the nurseries of Nebraska, Idaho, Washington, and California.

The Agricultural Experiment Station of Colorado has issued a bulletin on the Native Vegetation and Climate of Colorado in their Relation to Agriculture, prepared by Prof. Wilfred W. Robbins. The available temperature and precipitation data have been assembled, digested and discussed in their relation to vegetation and crop possibilities. Maps are given showing the distribution of mean summer temperatures, average length of frostless season, average date of last spring frost, and mean annual precipitation. After describing the climatic conditions for the state as a whole the author treats each of the vegetational regions in greater detail. The ten stations in the yellow pine forest region vary in mean annual precipitation from 14.79 inches at the dryest to 24.36 inches at the wettest. The growing season is shown to receive approximately half of this amount. The eleven stations in the sagebrush shrub-steppe vary in precipitation from 7.94 inches to 18.69 inches. Similar illuminating comparisons are made between the temperature conditions of these and other areas. In the discussion of climatic details and their relation to agricultural plants the author shows great familiarity with his state and with the problems under investigation. The large number of workers who will be interested in Professor Robbins' very compact bulletin will have a suspicion that he could have written one five times as thick without exhausting his data or the diversities of his state and its problems.

An important contribution to West Indian taxonomy has been made by Dr. Otto E. Jennings, who has published a list of the plants collected by himself and others in the Isle of Pines, and now contained in the herbarium of the Carnegie Museum. A very brief description of the vegetation of the island shows two of its important formations to be pine barren and open forest of slash pine, bearing considerable resemblance to the adjacent barrens of the province of Pinar del Rio in Cuba.

Prof. W. F. Ganong has contributed to the Smith Alumnae Quarterly an article describing the botanical equipment and curriculum of Smith College. The well known high standards which are maintained by Professor Ganong and his associates in the botanical department of this college give to all teaching botanists an interest in the equipment and methods which are there in use.

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THE REVEGETATION OF TAAL VOLCANO, PHILIPPINE ISLANDS

FRANK C. GATES

Carthage College, Carthage, Illinois

On January 30, 1911, culminated the last severely destructive eruption of Taal Volcano, of which Dean C. Worcester's description may be found in the April, 1912, number of the National Geographic Magazine. This eruption entirely destroyed all the villages on the island as well as some of those on the mainland, with the loss of about 1400 lives. Ashes, pumice, small stones, and acid vapors were spread over the island and thrown across the lake to the mainland, devastating the country to the west and southwest of the volcano. Ashes were in addition thrown over large areas of surrounding country, resulting in the defoliation of the vegetation not otherwise affected. The volcano was left bare of plants. It did not long remain plantless, however, as the following account of the pertinent facts of its revegetation up to March, 1915, will indicate.[1]

The volcano is a low mountain (304 meters) situated in a lake, known as Taal Lake or Lake Bombon, in Batangas Province, about 63 km. south of Manila, Luzon Island, P. I. The surface of the island is very rugged, due to the very active erosion brought about by the heavy tropical rains, 1750 to 2000 mm., which run off the steep slopes of the volcano with great rapidity. The active crater is in the center of the island. It is about 2.3 km. long and 1.7 km. wide at the top. More than half of the bottom is occupied by a lake, whose elevation is about 2.5 meters above sea level—the same as that of the surrounding Lake Bombon.

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[1] For a more detailed account, including an annotated list of the plants found on the volcano up to April, 1914, see Gates, F. C. "The Pioneer Vegetation of Taal Volcano." Philippine Jour. of Science, 9, Sect. C: 391–434, 1914, with plates III to X.

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The water of the crater lake is clear, although dark-colored, and salty. Its temperature decreased from about 37°C. in October, 1913, to about 32° in April, 1914, after which it began to increase. By March, 1915, it had reached 39° and a noticeable amount of steam was rising from the lake for the first time in my experience. Swimming in the crater lake, although much like salt water bathing, was, of course, much more exciting. In April, 1914, a little steam had been noted coming from vents in the north crater wall and from a few places along the shore of the lake. By March, 1915, a number of bubbling centers had developed, particularly in the southern half of the lake, more steam was issuing from the vents previously noted, and several additional vents had come into existence. From the first, sulfurous vapors were noticed from certain points in the crater rim, but none were detected in the bottom of the crater until March, 1915. Steep precipitous walls form the boundary of the crater on all sides. The crater rim is highest on the south and north sides, with altitudes of 304 and 230 meters, respectively, and lowest to the west, where it is but 95 meters high.

Previous to the eruption of 1911, the region outside of the crater was vegetated from the strand to the rim of the crater. The vegetation could be briefly summed up as trees, parang (thickets), grassland and culture in various combinations. Some trees over 75 cm. in diameter were present even on the crater slope. Within the crater a tree of *Ficus indica* was present. A number of barrios (villages) were located along the shore of Lake Bombon, particularly in the northern part of the island and in their vicinity a few cultivated plants have since been found.

While parts of a very few plants in certain well protected situations on the far sides of Mounts Bignay, Ragatan, Binintiang Malaki, and Balantoc did survive the rain of acid ash and mud and the mechanical violence of the eruption, vegetation over the rest of the island was entirely destroyed. No vegetation appeared until rains leached the acid out of the soil.

Except for sparing and very local regeneration in the areas mentioned above, no vegetation appeared in the first rainy

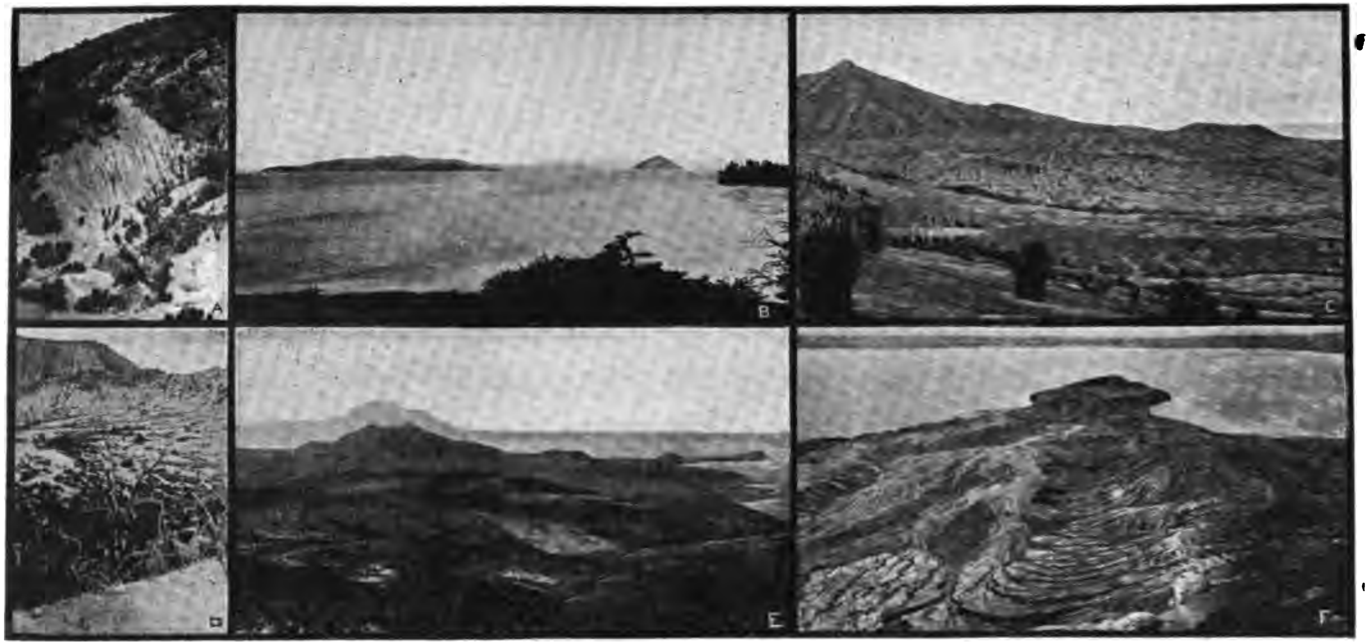


Fig. 1. A. Erosion along a stream course, showing bunches of *Saccharum spontaneum indicum.* October 25, 1913.

B. Taal Volcano from the observatory at Banadero. The dark areas in front of the volcano are bamboo-covered islands east of the volcano. The crater is in the left center and the peak on the right is Mt. Binintiang Malaki. April 21, 1914.

C. The region immediately west of the crater, showing the extreme scantiness of the vegetation. March 6, 1915.

D. The area within the horseshoe-shaped Mt. Balantoc, showing the greater amount of vegetation on the slopes less exposed to the violence of the eruption. The east end of Mt. Binintiang Malaki in the background. October 25, 1913.

E. Southward from Mt. Binintiang Malaki. Mt. Balantoc in the immediate foreground, the active crater in the left center just in front of the highest point on the island. Across the lake in the background is Mt. Macolod. March 6, 1915.

F. The southern end of the volcano island from the south rim of the crater. Vegetation is present only near the shore. March 6, 1915.

season, nor to any noteworthy extent in the dry season following. Revegetation began in earnest in the second rainy season with the invasion of the strand, at places along the northern coast and at the southern corner of the island, by the beach morning glory (*Ipomoea pes-caprae*) and a legume (*Canavalia lineata*) of similar appearance. At lower altitudes in the same rainy season grass plants appeared simultaneously on several of the slopes facing north and east. Talahib (*Saccharum spontaneum indicum*), which forms fully 75% of the grass on the island, is exceedingly abundant on the mainland, less than 10 km. distant. It seeds profusely at a time when the monsoon wind is favorable for distribution to the island. In the northwestern part of the island the dominant grass is *Themeda gigantea*. With no opposition, grass rapidly became established and spread in all directions, producing a dense stand at lower elevations. In October, 1913, except for one small patch of grass on the crater rim, there was no vegetation above 175 meters. The densest vegetation was below 100 meters. By December of that year the density of the grassland had increased and new clumps were found at higher elevations. In April, 1914, further advance was very conspicuous. Clumps of *Saccharum* were present on the slopes leading to the crater rim, at a few places on the rim, and even for about 10 meters down in the crater, as well as on all the higher ridges leading from the crater towards the north. The density had increased to a closed stand well up to 150 to 175 meters and even higher in a few places. At the southern end of the island, the grass was likewise spreading, but less rapidly. While in December, 1913, there were no plants whatsoever on the eastern and western slopes—the scenes of severest devastation—in April, 1914, about 50 isolated clumps of grass had put in appearance near the shore on the western slope and a somewhat greater number on the sides of the gullies near the shore on the eastern slope.

A little later than the appearance of grass in the second rainy season, but simultaneously over considerable areas, avevectant shrubs and small trees appeared in the grassland and to a limited extent also on bare ground. *Ficus indica* and *Morinda* *bracteata* were characteristic of the more open high slopes. *Acacia farnesiana, Tabernaemontana subglobosa, Pithecolobium dulce, Macaranga tanarius, Antidesma ghaesembilla, Psidium guajava, Trema amboinensis, Ficus ulmifolia, Cordia myxa, Casearia cinerea, Bridelia stipularis,* and *Callicarpa blancoi* dominated at lower elevations. In October, 1913, but one shrub (*Ficus indica*) was present on the outside of the crater wall above 150 meters. In April, 1914, a few shrubs of *Acacia farnesiana, Ficus indica,* and *Wendlandia luzoniensis* were present on the north rim of the crater and the high ridge, known as Mount Pinag-Ulbuan, leading northeast from it. A small bush of *Ficus indica* was growing on a ledge inside the crater some 50 meters below the rim.

The invasion of shrubs was general, taking place on the crests as well as on the sides of ridges. The crests of ridges present severe xerophytic conditions and are usually invaded only by such species as *Ficus indica, Acacia farnesiana,* and *Tabernaemontana subglobosa.* By October, 1913, the pioneer shrubs were themselves bearing seeds. The shrub grows up with the grass and spreads out over it. The resulting shade leads to the elimination of the grass and thus facilitates both the further distribution of shrubs and the invasion of trees. The spread of shrubs from such centers of distribution leads to the development of parang—thicket-like growth— and the final exclusion of the cogon grasses. By April, 1914, this had been accomplished in a few places, notably in the region of the northeast cape. A large number of shrubs, many vines and lianas and a few trees had converted the area into a jungle.

In the short time thus far elapsed, only a few tree species were present. *Trema amboinensis* and *Cordia myxa,* small parang trees, were most abundant. Their dominance was complete in certain places in the northern parts of the island.

It was quite evident that the trend of vegetation is towards the development of a tree cover over the greater part of the island. From bare ground, both grass and parang usually precede the development of trees. By April, 1914, the tree form of vegetation was further represented by seedlings and small trees

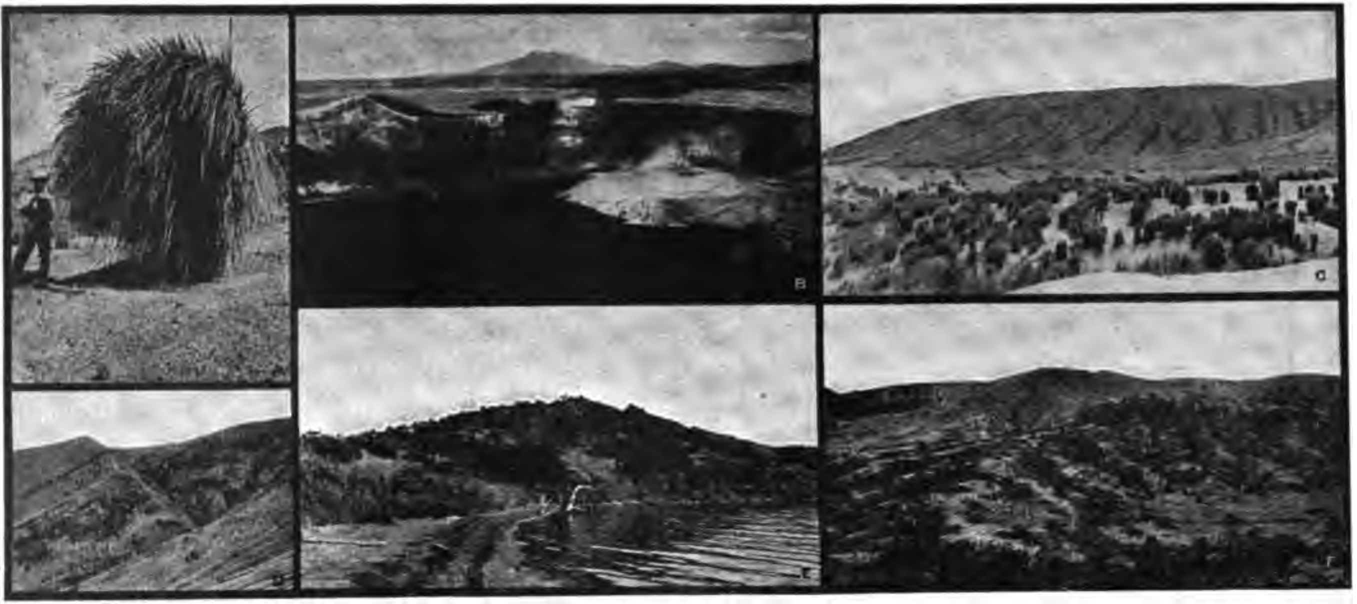


Fig. 2. A. A typical bunch of *Saccharum spontaneum indicum*. March 6, 1915.

B. Northeastward across the crater. To the east of the crater lake in the extreme right foreground are clumps of grass on the floor of the crater. March 6, 1915.

C. West side of Mt. Pinag-Ulbuan, illustrating grass invasion on flats and up the valleys. October 25, 1913.

D. Illustrating erosion along a stream course, October 25, 1913.

E. From the east coast north to Mt. Bignay, the region of highest vegetational development. Dark areas are trees, light areas represent grassland, while close to the shore are marsh plants. March 7, 1915.

F. Southwest from Mt. Bignay showing, on the left, an old crater; in the center Mt. Pinag-Ulbuan, running to the crater rim; and, on the right, Mt. Mataas-na-golod, in front of which is Mt. Ragatan. Light areas are covered with grass (*Saccharum spontaneum indicum* and *Imperata cylindrica koenigii*), while dark areas are covered with shrubs and small trees, especially *Ficus indica, Acacia farnesiana, Morinda bracteata* and *Trema amboinensis*. March 7, 1915.

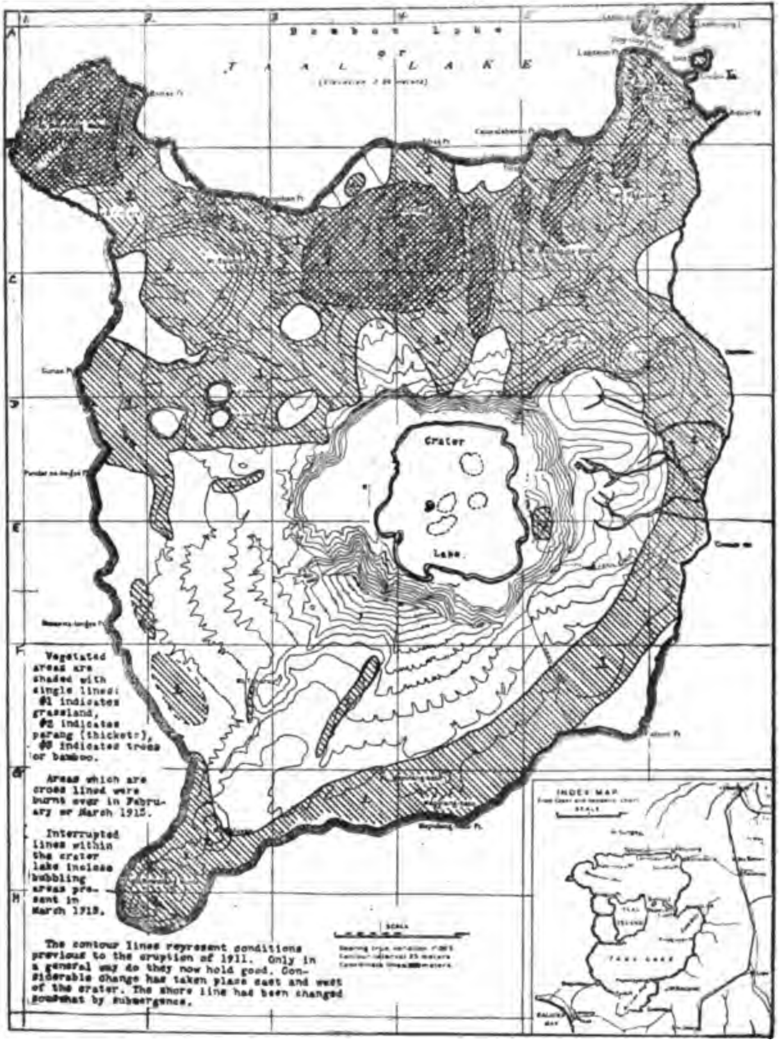
of *Sterculia foetida*, *Albizzia procera*, *Alstonia scholaris*, *Litsea glutinosa*, *Mallotus moluccanus*, *Melicope triphylla*, *Oroxylum indicum*, *Premna nauseosa*, *Cratoxylon blancoi*, *Eugenia jambolana*, *Ficus hauili*, *Wrightia laniti*, *Vitex parviflora*, *Erythrina indica*, *Muntingia calabura*, and the tree-like grass, *Bambusa blumeana*. Trees were already dominant in places in the northern part of the island near the water level, particularly on the slopes of Mounts Binintiang Malaki and Pirapiraso. For the most part trees occurred isolated in the parang.

Between April, 1914, and March, 1915, the area of vegetation increased considerably in extent. Invasion of hitherto unvegetated areas was most conspicuous along the eastern and western coasts and within the crater. Near the shore along the eastern coast, clumps of grass have appeared in all the gullies and on most of the ridges along the entire coast, thus connecting the northern and southern distributional centers. Shrubs had not yet begun to assert themselves, although seedlings were present. Along the western coast, progress, although evident, was less extensive. Tongues of grass from the northern and southern centers of distribution were progressing towards each other. In suitable situations in the intervening space, clumps of *Saccharum* were growing. No shrubs were present. Within the crater many clumps of *Saccharum* were present on ledges in the north wall, but the single shrub of *Ficus indica* was still the only representative of parang conditions. No vegetation whatsoever was present on the east, west or south walls of the crater. On the floor of the crater—hitherto plantless—about 150 clumps of *Saccharum* were now growing east of the crater lake and a single clump west of the lake. The healthy growth of these clumps would tend to indicate that vegetation is going to play a more conspicuous rôle within the crater than it did previous to the last eruption On the other hand, the increasing temperature of the crater lake, the appearance of bubbling areas (four of which were between 50 and 100 meters across), the increasing amount of steam and sulphurous vapors together with the softening of the mud may well result in the early elimination of this vegetation.

During the same time the density of the vegetation increased over the entire vegetated part of the island. In the northern fourth of the island the rapid growth of small trees was swiftly changing wide areas from grassland to a thicket or parang condition. During the unusually heavy rains of the rainy season of 1914, erosion was very pronounced. Many clumps of *Saccharum* were washed from their positions on the outer slope of the crater rim. Losses of grass area thus brought about, taken with the rapidly increasing ascendency of the parang in the grassland, were not compensated by the gains along the east and west coasts. Consequently there was an actual decrease in the amount of grassland on the island.

In the early part of the dry season of 1915, parang and tree conditions received a severe setback in certain parts of the island due to fires set by Filipino fishermen. The northeast cape, the area of highest vegetational development, suffered comparatively little. Light burns swept the parang from certain of the ridges but did not severely injure vegetation in the valleys. Mount Binintiang Malaki, on which vegetation had progressed into the small tree stage, was completely devastated. The distribution and approximate extent of the fires of February and March, 1915, are shown on the accompanying map.

In the course of a few years both the grass and the parang should be replaced by trees wherever conditions are favorable for trees. This succession is taking place most rapidly in the northern fourth of the island but has also commenced on Mount Binintiang Munti at the southern corner. Its progress has been most rapid in the northeastern and northwestern corners. Fire in the latter region, however, has given the vegetation there a severe setback. No vegetation has yet secured a hold on the severely devastated area immediately west of the crater, nor on the steep slopes of the southern part of the crater rim, where erosion is still very active and the exposure to the sun most severe. It is logical to expect that this development will go on, faster on the northern than on the southern sides, until the slopes are covered with vegetation. Trees and shrubs will occupy the sides of ridges, while the crest is more likely to be occupied with grass for a time, but ultimately should also become forested.



Vegetated areas are shaded with single lines: #1 indicates grassland, #2 indicates parang (thickets), #3 indicates trees or bamboo.

Areas which are cross lined were burnt over in February or March 1915.

Interrupted lines within the crater lake inclose bubbling areas present in March 1915.

The contour lines represent conditions previous to the eruption of 1911. Only in a general way do they now hold good. Considerable change has taken place east and west of the crater. The shore line has been changed somewhat by submergence.

Fig. 3. Map of Taal Volcano, showing the area revegetated up to March, 1915.

The development of the dipterocarp forest, normal for such altitudes in this region, is possible, although very improbable, for accidents in the shape of eruptions are likely to intervene, before it has had sufficient time to develop. Dipterocarps are present on Mount Makiling, 34 km. to the northeast, but seeding takes place during the southwest winds. The heavy seeds of the dipterocarp, *Parashorea plicata* Brandis have been found a little over a kilometer from the nearest parent tree, but could no doubt be carried considerably further in severe typhoon winds.

Bubbling areas and the increase in temperature of the crater lake are positive evidence that Taal is still a live volcano and that vegetation may again be compelled to commence with bare ground.

STRUCTURE OF THE VEGETATION

The nine plant associations on Taal Volcano may be grouped in three genetic series.

The Aquatic Series. This series, in which aquatic plants tend to build up the bottom of a body of water, was poorly represented in a few places by the Vallisneria Association. In rooted plants of *Vallisneria gigantea,* such floating plants, as *Ceratophyllum demersum, Pistia stratiotes* and *Lemna trisulca,* were frequently enmeshed.

The Marsh Series. This series inhabiting wet ground in progressively drier stages to dry ground is clearly indicated in a few places on the island, but nowhere is either well developed or extensive. The Cynodon, Panicum repens, and Phragmites Associations are present.

The Dry Ground Series. To this series belong the associations which form 98% of the vegetated area of the island. Four formations may be easily recognized. The Strand Formation, represented by the Ipomoea pes-caprae and Sesbania associations, occurs quite frequently on the beach. The physiological requirements of the plants keep them down close to the water edge, although there are seldom any plants immediately in back of them to keep them from spreading up beyond the strand.

The Cogonal or Grassland Formation is the best developed and most extensive on the island. The Cogon Association, in one or another of four consocies, is the pioneer association in the revegetation of the greater part of Taal Volcano. The Saccharum spontaneum Consocies is first in importance. The Themeda gigantea and the Imperata cylindrica Consocies are of less importance—the former in the northwestern part of the island and the latter near Pirapiraso in land formerly cultivated. A fourth consocies, dominated by *Miscanthus sinesis*, is indicated by the presence of a few clumps of this grass.

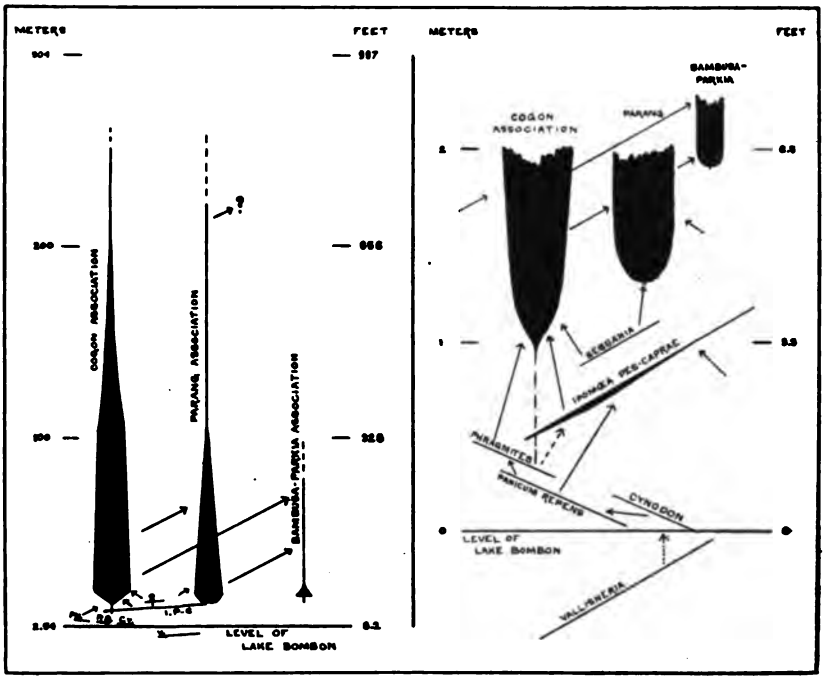


Fig. 4. Diagrams showing the successions exhibited between the plant associations on Taal Volcano, P. I. 1914. The approximate distribution in altitude is shown by the extent of the lines with reference to the scale on the left. The relative abundance of the associations at various altitudes is indicated by the thickness of the lines. Arrows pointing above the horizontal indicate succession to a higher genetic association. (Reproduced without change from Phil. Journ. Sci., 9, C, No. 5.)

The woody plants are easily divided into two formations: the Parang or Shrub-Small-Tree Formation and the Tree Formation. In the former is the Parang Association with numerous consocies, among which the Ficus indica, Tabernaemontana, Acacia farnesiana, and Morinda Consocies are conspicuous shrub consocies, and *Trema*, *Cordia*, and *Pithecolobium dulce* are each dominant in small tree consocies. As development of patches of shrubs goes on, the consocial lines become obliterated and a heterogeneous mixture, which may be termed General Parang is brought about. Into this, species of the Low Altitude Tree Formation readily invade. The only association so far evident is the Bambusa-Parkia Association, an association of trees, such as, *Albizzia procera*, *Oroxylum indicum*, *Wrightia laniti*, *Eugenia jambolana*, *Sterculia foetida*, *Erythrina indica*, *Mallotus moluccanus*, and *Ficus hauili*, together with the tree-like grass, *Bambusa blumeana*.

The Dipterocarp Association, the climax association for this general region is not even indicated. Its appearance on Taal Volcano, even after many years, is rather doubtful.

The weeds on the volcano may be grouped into a weed association, as yet of relatively little importance. The same is true of cultivated plants, of which a few plants remain from former cultivation and others have been reintroduced. As the island is uninhabited by law, few are to be expected.

No mention of mosses and lichens has been made in connection with the development of the vegetation because their appearance was subsequent to the appearance of higher plants. In the revegetation of Krakatoa, ferns were of considerable importance, but in the revegetation of Taal, ferns are a very minor element, due to the low altitude of the volcano, the exceeding dryness of the island, and the paucity of ferns on the neighboring mainland. Taal agrees with Krakatoa in that species distributed by water and wind appeared before species distributed by birds. On account of the much shorter distances (3.2 to 13 km.) involved in the case of Taal Volcano, revegetation was accomplished in a much shorter time.

With the addition of the following eight species, representing six additional genera and four additional families, to the previously recorded list,[2] the flora of Taal Volcano is brought up to March, 1915. By *Polygonum tomentosum*, the family Polygonaceae became represented; by *Otophora fruticosa*, the Sapindaceae; by *Blechum brownei*, the Acanthaceae; and by *Aristolochia tagala*, the Aristolochiaceae. The Apocynaceae were further represented by *Voacanga globosa;* the Moraceae by *Ficus* (probably) *concinna;* the Rutaceae by *Melicope triphylla;* and the Poaceae by *Saccharum officinarum*, the sugar cane. The following table brings the summary of higher plants found on the island since the eruption up to March, 1915.

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[2] Loc. cit., 422–430.

	FAMILIES	GENERA	SPECIES
Pteridophyta (Ferns)	3	7	9
Spermatophyta: (Seed plants)			
Monocotyledoneae	10	25	33
Dicotyledoneae-Axiflorae	33	69	89
Dicotyledoneae-Calyciflorae	15	48	56
Totals	61	149	187

List of species mentioned, with authorities

Acacia farnesiana (L.) Willd.
Albizzia procera (Roxb.) Benth.
Alstonia scholaris (L.) R. Br.
Antidesma ghesaembilla Gaertn.
Aristolochia tagala Cham.
Bambusa blumeana Schultes f.
Blechum brownei Juss.
Bridelia stipularis (L.) Blume.
Callicarpa blancoi Rolfe.
Canavalia lineata (Thunb.) DC.
Casearia cinerea Turcz.
Ceratophyllum demersum L.
Cordia myxa L.
Cratoxylon blancoi Blume.
Cynodon dactylon (L.) Pers.
Erythrina indica Lam.
Eugenia jambolana Lam.
Ficus concinna Miq.
Ficus hauili Blanco.
Ficus indica L.
Ficus ulmifolia Lam.
Imperata cylindrica koenigii (Retz.) Benth.
Ipomoea pes-caprae (L.) Roth.
Lemna trisulca Hegelm.
Litsea glutinosa (Lour.) C. B. Rob.
Macaranga tanarius (L.) Muell.-Arg.
Mallotus moluccanus (L.) Muell.-Arg.
Melicope triphylla (Lam.) Merr.
Miscanthus sinensis Andr.
Morinda bracteata Roxb.
Muntingia calabura L.
Otophora fruticosa Blume.
Oroxylum indicum (L.) Vent.
Panicum repens L.
Phragmites vulgaris (Lam.) Trin.
Pistia stratiotes L.
Pithecolobium dulce (Roxb.) Benth.
Polygonum tomentosum Willd.
Premna nauseosa Blanco.
Psidium guajava L.
Saccharum officinarum L.
Saccharum spontaneum indicum Hack.
Sesbania cannabina (Retz.) Pers.
Sterculia foetida L.
Tabernaemontana subglobosa Merr.
Themeda gigantea (Cav.) Hack.
Trema amboinensis Blume.
Vallisneria gigantea Graebn.
Vitex parviflora Juss.
Voacanga globosa Merr.
Wendlandia luzoniensis DC.
Wrightia laniti (Blanco) Merr.

AN ENUMERATION OF THE PTERIDOPHYTES AND SPERMATOPHYTES OF THE SAN BERNARDINO MOUNTAINS, CALIFORNIA

S. B. PARISH

San Bernardino, California

LILIACEAE

Allium anceps Kellogg, Proc. Cal. Acad. **2**: 109, f. 32.
Dry gravelly ridges, Bear Valley.

Allium bisceptrum Wats. King's Expl. **5**: 351, t. 37, f. 1–3.
Hillsides in the Transition Zone.

Allium Parryi Wats. Proc. Am. Acad. **14**: 231.
Abundant on dry slopes in Bear Valley, the type station.

Muilla serotina Greene, Eryth. **1**: 152.
Frequent on dry hillsides in the Chaparral Zone.

Bloomeria crocea Coville, Contr. Nat. Herb. **4**: 203.
Frequent on dry hillsides in the Lower Chaparral Zone.

Brodiaea capitata Benth. Pl. Hartw. 336.
Frequent on dry hillsides in the Chaparral and Lower Transition zones.

Brodiaea filifolia Wats. Proc. Am. Acad. **17**: 381.
Locally abundant in moist adobe soil at Arrowhead Hot Springs, the type station.

Brodiaea grandiflora Smith, Trans. Linn. Soc. **10**: 2.
On flats, Little Bear Valley, in the Lower Transition Zone.

Smilacina sessilifolia Nutt.; Wats. Proc. Am. Acad. **14**: 245.
Occasional in damp, shady places in the Transition Zone.

Nolina Parryi Wats. Proc. Am. Acad. **14**: 247.
Locally abundant on dry hillsides in the Piñon Zone; Rattlesnake Cañon and Morongo King Mine.

Yucca (Cleistoyucca) brevifolia Engelm. King's Expl. **5**: 496.
Occasional, ascending from the Mojave Desert into the Piñon Zone.

Yucca (Hesperoyucca) Whipplei Torr. Bot. Mex. Bound. 222.
Frequent on dry hills in the Lower Chaparral, and occasional in the Piñon Zone.

Lilium Humboldtii Roezl & Leicht.; Regel, Gartenf. 1872, t. 724.
Frequent in dry rocky or gravelly soil in the Upper Chaparral, and occasional in the Lower Transition Zone.

Lilium Parryi Wats.; Parry, Proc. Davenp. Acad. **2**: 188, t. 5, 6.
In bogs and by stream banks in the Transition Zone.

Fritillaria atropurpurea Nutt. Journ. Acad. Philad. **7**: 54.
Occasional on gravelly flats in the Transition Zone.

Calochortus concolor Purdy, Proc. Cal. Acad. III. Bot. **2**: 135.
Occasional on bushy hillsides, Mill Creek Cañon, in the Lower Chaparral Zone.

Calochortus invenustus Greene, Pitt. **2**: 71.
Abundant on dry slopes and flats, Bear Valley.

Calochortus invenustus Greene var. *montanus* Parish, Bull. S. Cal. Acad. **1**: 124.
Frequent, growing with the species.

Calochortus Plummerae Greene, Pitt. **2**: 70.
Frequent on dry hillsides in the Lower Chaparral Zone.

Calochortus splendens Dougl.; Benth. Trans. Hort. Soc. II. **1**: 411, t. 15. f. 1.
Frequent on dry hillsides in the Chaparral and Lower Transition Zones.

Veratrum californicum Durand, Journ. Acad. Philad. **3**: 103. *V. speciosus* Rydb. Bull. Torr. Club **27**: 532.
Frequent, growing in dense ranks in marshy stream banks in the Transition Zone.

Iris Hartwegii Baker var. *australis* Parish, Eryth. **6**: 86.
Frequent on dry hillsides and flats in the Lower Transition Zone.

Iris missouriensis Nutt. Journ. Acad. Philad. **7**: 58.
Densly and extensively caespitose in wet meadows in Bear Valley.

Sisyrinchium sp.
Frequent on hillsides and in flats in the Transition Zone. A segregate of *S. bellum* Wats.

ORCHIDACEAE

Coralorrhiza multiflora Nutt. Journ. Acad. Philad. **3**: 138, t. 7.
Common in coniferous forest in the Transition and Canadian Zones.

Epipactis gigantea Dougl.; Hook. Fl. Bor. Am. **2**: 202, t. 202.
Occasional in damp shady places in the Chaparral and Transition Zones.

Spiranthes porrifolia Lindl. Orchid. 467.
Abundant in wet meadows, Bluff Lake.

Habenaria elegans Bolander; Wats. Bot. Cal. **2**: 133.
Occasional on dry slopes in the Lower Transition Zone.

Habenaria laxiflora Parish, comb. nov. *Limnorchis laxiflora* Rydb. Bull. Torr. Club **28**: 630.
Whitewater Basin, Transition Zone, *Mrs. Wilder*.

Habenaria longispicata Parish, comb. nov. *Gymndaenia longispicata* Durand, Journ. Acad. Philad. 1855: 101.
Vivian Creek, Canadian Zone, *G. B. Grant*.

Habenaria leucostachys Wats. Bot. Cal. **2**: 134.
Common in wet meadows in the Upper Transition Zone.

Habenaria sparsiflora Wats. Proc. Am. Acad. **12**: 276.
Mill Creek Cañon in the Transition Zone.

Habeneria Thurberi Gray, Proc. Am. Acad. **7**: 389.
In meadows in the Upper Transition Zone.

SALICACEAE

Salix cordata Muhl. var. *Watsoni* Bebb in Wats. Bot. Cal. **2**: 86.

On the rocky sides of Snow Cañon, Canadian Zone.

Salix exigua Nutt. Sylva **1**: 75.

Frequent along stream banks in the Chaparral, Lower Transition and Piñon Zones.

Salix flavescens Nutt. Sylva **1**: **65**.

Frequent in springy soil in the Canadian Zone.

Salix lasiandra Benth. var. *fendleriana* Bebb in Wats. Bot. Cal. **2**: 84.

Borders of meadows and streams, Bear Valley and Bluff Lake.

Populus trichocarpa T. & G.; —— Hook, Ic. **10**: 878.

Infrequent along streams in the Lower Chaparral Zone.

Populus trichocarpa T. & G. var. *ingrata* Parish, comb. nov. *P. trichocarpa* T. & G. f. *ingrata* Jeps. Syl. Cal. 189.

Frequent along streams in the Upper Transition and Canadian Zones.

JUGLANDACEAE

Juglans californica Wats. Proc. Am. Acad. **10**: 349: California Walnut

On dry banks in cañons of the Lower Chaparral Zone; a large shrub or small tree.

BETULACEAE

Alnus rhombifolia Nutt. Syl. **1**: 33. Alder

Abundant, bordering streams in the Lower Chaparral Zone.

FAGACEAE

Quercus chrysolepis Leibm. Dansk. Vid. Forh. 1854: 175. Live Oak

Frequent on dry cañon sides in the Chaparral Zone. A tree 25–40 ft. high.

Quercus dumosa Nutt. Syl. **1**: 7 Scrub Oak

Frequent on dry cañon sides in the Lower Chaparral Zone. A shrub 5–12 ft. high.

Quercus Kelloggii Newb. Pac. R. Rept. **6**: 28 Mountain Oak

Common on flats and slopes in the Transition Zone. At lower altitudes a spreading tree, 40–50 ft. high, but at its upper limits reduced to a large shrub.

Quercus Wislizeni A. DC. Prodr. **16**^{2}: 67.

On dry hillsides in the Upper Chaparral Zone. A large shrub.

Castinopsis sempervirens Dudley; Merriam N. A. Fauna **15**: 142. Chinquapin

Abundant, forming dense thickets, in the Upper Transition and Canadian Zones.

LORANTHACEAE

Phoradendron densum f. *Parishii* Trel. Monog. Phorad. **28**, t. 21.

On *Juniperus californicus* Carr.

Phoradendron ligatum Trel. Monog. Phorad. 24, t. 3, 15.

On *Juniperus occidentalis* Hook.

Phoradendron libocedri Howell, Fl. N. W. Am. **1**: 608

On *Libocedrus decurrens* Torr.

Phoradendron longispicatum Trel. Monog. Phorad. 39, t. 38, 39.
On *Alnus* and *Salix* in the Lower Chaparral Zone.

Phoradendron villosum Nutt. Journ. Philad. Acad. n.s. **1**: 85.
On *Quercus Kelloggii* Newb. in the Lower Transition Zone, and rarely on other oaks.

Arceuthobium campylopodum Engelm. Journ. Bost. Soc. Nat. Hist. **6**: 214.
On *Pinus Coulteri* Don.

Arceuthobium divaricatum Engelm. in Rothr. Wheeler's Surv. **6**: 253.
On *Pinus monophylla* Torr. & Frem.

POLYGONACEAE

Polygonum amphibium Linn. Sp. Pl. 361. *P. insignis* Greene, Leafl. **1**: 32.
Floating in ponds and reservoirs in the Upper Transition and Canadian Zones.

Polygonum bistortoides Pursh, Fl. **1**: 271. *P. bernardinum* Greene, Pitt. **5**: 198.
Common in wet meadows in the Transition Zone.

Polygonum Douglasii Greene, Bull. Cal. Acad. **1**: 125.
Common in pine forest in the Transition Zone.

Polygonum Watsoni Small, Monog. N. A. Polyg. 138, t. 36.
On moist sand banks, Bluff Lake and Bear Valley.

Rumex crispus Linn. Sp. Pl. 335.
Infrequent in meadows, Bear Valley. Introduced.

Rumex maritimus Linn. var. *fueginus* Dusen, Svenka Exp. Magell. **3**: 194.
Common on moist sandbanks, Bear Valley.

Rumex salicifolius Weinm. Flora **4**: 28.
Frequent near stream banks in the Chaparral and Transition Zones.

Pterostegia drymarioides F. & M. Ind. Sem. Petrop. **2**: 48.
Frequent on dry banks in the Lower Chaparral Zone.

Oxytheca caryophylloides Parry, Proc. Davenp. Acad. **5**: 175.
On open slopes in the Lower Transition Zone; the type region.

Oxytheca Parishii Parry, Proc. Davenp. Acad. **5**: 176.
Frequent on open slopes in the Lower Transition Zone; the type region.

Eriogonum fasciculatum Benth. Trans. Linn. Soc. **17**: 411.
Abundant on dry hillsides in the Lower Chaparral Zone.

Eriogonum inerme Jeps. Fl. Cal. 406.
In open ground in the Lower Transition Zone.

Eriogonum Kennedyi Porter; Wats. Proc. Am. Acad. **12**: 265.
Common, forming depressed mats, on open banks, Bear Valley.

Eriogonum molestum Wats. Proc. Am. Acad. **17**: 379.
Frequent in open pine forest in the Lower Transition Zone.

Eriogonum ovalifolium Nutt. var. *vineum* Jeps. Fl. Cal. 423.
Rocky pass between Doble (Bear Valley) and Rose Mine, and in the lower part of Cushenberry Cañon. The flowers vary from creamy white to pink and deep claret color.

Eriogonum Parishii Wats. Proc. Am. Acad. **17**: 379.
Common on dry open hillsides in the Upper Transition Zone; the type region.

Eriogonum saxatile Wats. Proc. Am. Acad. **12**: 267.
Frequent in sandy or rocky soil in the Lower Transition Zone.

Eriogonum saxatile Wats. var. *Stokesae* Parish, comb. nov. *E. Stokesae* Jones, Contr. W. Bot. 8: 39.

On dry flats in the Lower Transition Zone.

Eriogonum umbellatum Torr. var. *stellatum* Jones, Contr. W. Bot. 11: 5.

Dry ridges at Doble (Bear Valley); Summit of San Gorgonio, *Wright*.

Eriogonum vimineum Dougl.; Benth. Trans. Linn. Soc. 11: 416.

Occasional on dry banks in the Transition Zone; Mill Creek.

Eriogonum Wrightii var. *subscaposum* Wats. Bot. Cal. 2: 29.

Frequent on rocky ridges in the Upper Transition and Canadian Zones.

CHENOPODIACEAE

Monolepis nuttaliana Greene, Fl. Franc. 168.

On the borders of ponds, Bear Valley.

AMARANTHACEAE

Amaranthus californicus Wats. Bot. Cal. 2: 42.

Occasional on flats in the Transition Zone.

NYCTAGINACEAE

Abronia nana Wats. Proc. Am. Acad. 14: 294.

Rose Mine and in one locality in Bear Valley; rare and not otherwise known in California.

Mirabilis californica Gray, in Torr. Bot. Mex. Bound. 169, t. 48.

Frequent on dry or rocky banks in the Lower Chaparral Zone.

Mirabilis californica Gray var. *aspera* Jeps. Fl. Cal. 458.

Frequent on dry or rocky banks in the Lower Piñon Zone.

PORTULACACEAE

Calyptridium Parryi Gray, Proc. Am. Acad. 22: 285.

Abundant on damp sandy flats in Bear Valley, the type station.

Spraguea umbellata Torr. Pl. Frem. 4, t. 1. Pussy Feet

Common on sandy or gravelly soil throughout the Transition Zone.

Calandrinia Breweri Wats. Proc. Am. Acad. 11: 124.

Local on City Creek road, Upper Chaparral Zone; not otherwise known in southern California.

Montia Chamissoi Dur. & Jack. Index Kew. Supp. 1: 282.

Frequent on wet banks in Bear Valley. South Fork Santa Ana River, *Mrs. Wilder*.

Montia perfoliata Howell, Eryth. 1: 38.

Frequent on damp shady banks in the Chaparral Zone and occasional in the Lower Transition Zone.

Lewisia brachycalyx Engelm.; Gray, Proc. Am. Acad. 7: 400.

Locally abundant in wet meadows, mouth of Grout Creek (Bear Valley); the only known station in California.

Lewisia rediviva Pursh, Fl. 2: 368. Bitter Root

Locally abundant on stony banks in Bear Valley. The southernmost station in California.

CARYOPHYLLACEAE

Stellaria borealis Bigel. Fl. Bost. ed. 2, 182.
South Fork of Santa Ana River, Upper Transition Zone, *Mrs. Wilder.*
Stellaria longipes Goldie, Edenb. Phil. Journ. 6: 327.
Frequent in wet meadows in the Upper Transition Zone.
Stellaria nitens Nutt.; T. & G. Fl. 1: 185.
Occasional on dry shaded slopes in the Chaparral and Lower Transition Zones.
Sagina Linnaei Presl. Rel. Haenk. 2: 14.
Infrequent in cold bogs. Bluff Lake; Bear Valley Dam.
Arenaria capillaris Poir var. *ursina* Robins. in Gray, Synop. Fl. 1 pt. 1: 240.
Frequent on dry gravelly banks Bear, Valley; the type station.
Arenaria Nuttallii Pax. var. *gracilis* Robins. Proc. Am. Acad. 29: 304.
On the summit of San Gorgonio Mountain, *Wright.*
Arenaria saxosa Gray, Pl. Wright. 2: 18.
A single plant, Upper Santa Ana Cañon, alt. 8200 ft. *Hall;* acc. Jeps. Fl. Cal. The only reported occurrence of the species in California.
Silene laciniata Cav. Ic. 6: 44, t. 564.
Frequent on shrubby banks in the Lower Chaparral Zone.
Silene Lemmoni Wats. Proc. Am. Acad. 10: 342.
Frequent in open pine forest in the Transition Zone.
Silene Menziesii Hook. Fl. Am. Bor. 1: 90, t. 30.
Occasional on damp shaded banks in Bear Valley.
Silene Parishii Wats. Proc. Am. Acad. 17: 366.
Occasional among rocks or in decomposed granite, Bear Valley; the type station.
Silene verecunda Wats. var. *platyota* Jeps. Fl. Cal. 509.
Frequent in open pine forest in the Transition Zone.

CERATOPHYLLACEAE

Ceratophyllum demersum Linn. Sp. Pl. 992.
Abundant, floating in ponds, and now in the reservoir, Bear Valley.

RANUNCULACEAE

Paeonia Brownii Dougl.; Hook. Fl. Bor. Am. 1: 27. Wild Peony
Occasional on dry banks in the lower Chaparral Zone.
Actaea spicata Linn. var. *arguta* Torr. Pac. R. Rep. 4: 63.
Occasional in the Transition Zone.
Aquilegia truncata F. & M. Ind. Sem. Petrop. 9, Supp.: 8. Columbine
Common on bushy cañon sides in the Chaparral Zone.
Aquilegia truncata F. & M. var. *pauciflora* Jeps. Fl. Cal. 517.
Common on moist banks in the Canadian Zone.
Delphinium cardinale Hook. Bot. Mag. t. 4887. Scarlet Larkspur
Frequent among shrubs in the Lower Chaparral Zone.
Delphinium decorum F. & M. Ind. Sem. Petrop. 3: 33.
Infrequent in cañons of the Lower Chaparral Zone.

Delphinium Parryi Gray, Bot. Gaz. **12**: 53. Blue Larkspur
Common on shrubby cañon-sides in the Lower Chaparral Zone.

Delphinium Parishii Gray, Bot. Gaz. **12**: 53.
A desert species, ascending the cañons of the Piñon Zone to Bear Valley.

Delphinium scopulorum var. *glaucum* Gray, Pl. Wright. **2**: 9.
Bluff Lake, *Miss Nora Pettibone.*

Thalictrum polycarpum Wats. Bot. Cal. **2**: 425.
Common near streams in the Chaparral and Lower Transition Zones.

Thalictrum Fendleri Engelm. var. *platycarpum* Trel. Proc. Bost. Nat. Hist. Soc. **23**: 304.
Stream banks, Bear Valley.

Thalictrum sparsiflorum Turcz. Ind. Sem. Petrop. **1**: 46.
Stream banks, Bear Valley.

Myosurus apetalus Gay, Fl. Chil. **1**: 31.
Borders of reservoir, Bear Valley.

Clematis lasiantha Nutt.; T. & G. Fl. **1**: 9.
Frequent, clambering over shrubs, in the Upper Chaparral Zone.

Clematis ligusticifolia Nutt.; T. & G. Fl. **1**: 9.
Occasional, clambering over shrubs and trees in the Lower Transition Zone.

Ranunculus alismaefolius Geyer var. *alismellus* Gray, Proc. Am. Acad. **7**: 327.
Frequent on wet banks; Bluff Lake and Bear Valley.

Ranunculus aquatilis Linn. var. *trichophyllus* Gray, Man. ed. 1, 40.
Frequent in shallow ponds, slow streams and reservoirs in the Transition Zone.

Ranunculus Cymbalaria Pursh var. *saximontanus* Fernald, Rhod. **16**: 162.
Frequent in wet soil in the Chaparral and Transition Zones.

Ranunculus Eschscholtzii Schlect. Anamad. Ran. **2**: 116, t. 1.
Summit of San Gorgonio Mountain, *Mrs. Wilder, Wright.*

Ranunculus latilobus Parish, comb. nov. *R. californicus* Benth. var. *latilobus* Gray, Proc. Am. Acad. **21**: 375.
Abundant in meadows in Bear Valley.

Ranunculus tenellus Nutt.; T. & G. Fl. **1**: 23.
Frequent in meadows in the Lower Transition Zone.

Ranunculus reptans Linn. Sp. Pl. 549.
Frequent on wet banks in the Lower Transition Zone.

LAURACEAE

Umbellularia californica Nutt. Syl. **1**: 87. Laurel
Frequent in the cañons of the Upper Chaparral Zone. A large shrub; never arborescent.

PAPAVERACEAE

Platystemon californicus Benth. Trans. Hort. Soc. II, **1**: 405. Cream Cups
Frequent in sandy soil in the Lower Chaparral Zone.

Platystigma denticulatum Greene, Bull. Torr. Club **13**: 218.
Occasional on shaded hillsides in the Lower Chaparral Zone.

Dendromecon rigidum Benth. Trans. Hort. Soc. II, **1**: 407. Bush Poppy

Frequent on hillsides in the Lower Chaparral Zone.

Argemone platyceras Link & Otto, Ic. Pl. Rar. **1**: 85, t. 43.

Occasional in dry washes in the Chaparral and Piñon Zones, and rare as high as 8000 feet altitude.

Eschscholtzia californica Cham. in Nees, Hort. Phys. Berol. **75**: 15. Perennial California Poppy

Occasional in the Upper Chaparral Zone. Includes *E. nitrophila* Greene, Pitt. **5**: 240, abundant at Doble (Bear Valley), the type station.

Eschscholtzia minutiflora Wats. Proc. Am. Acad. **11**: 122.

A desert species which ascends the cañons of the Lower Piñon Zone.

CRUCIFERAE

Draba corrugata Wats. Bot. Cal. **2**: 430.

On the summit of San Gorgonio Mountain, and in the Hudsonian island in Snow Cañon, Mill Creek.

Draba Douglasii Gray, Proc. Am. Acad. **7**: 328.

Rare on stony slopes, Bear Valley.

Athysanus pusillus Greene, Bull. Cal. Acad. **1**: 72.

A foothill species which ascends the Lower Chaparral Zone.

Thysanocarpus curvipes Hook. Fl. Bor. Am. **1**: 69, t. 18, f. A.

Occasional on shaded hillsides in the Lower Chaparral Zone.

Thysanocarpus laciniatus Nutt.; T. & G. Fl. **1**: 118.

Occasional on shaded hillsides in the Lower Chaparral Zone.

Lesquerella sp.

A single specimen, on a dry slope in open pine forest at Metcalfs (Bear Valley), *Chandler*.

Lepidium bernardinum Abrams, Bull. Torr. Club **37**: 149.

Bear Valley, type station.

Lepidium Menziesii DC. Syst. **2**: 539.

In sandy soil, Waterman Hot Springs, in the Lower Chaparral Zone.

Lepidium nitidum Nutt.; T. & G. Fl. **1**: 116.

Occasional on hillsides in the Chaparral Zone.

Sisymbrium canescens Nutt. Gen. **2**: 68.

Occasional in dry soil in the Chaparral and Lower Transition Zones.

Sisymbrium incisum Engelm.; Gray, Pl. Fendl. **1**: 152, t. 64.

Frequent on the borders of shallow ponds in the Transition Zone.

Sisymbrium officinale Scop. Fl. Carn. ed. 2, 26.

Frequent in dry soil in the Chaparral and Lower Transition Zones. Naturalized from Europe.

Erysimum asperum DC. Syst. **2**: 505.

Frequent on dry hillsides in the Chaparral and Transition Zones.

Radicula curvisiliqua Greene, Leafl. **1**: 113.

Occasional on the borders of desiccating ponds in the Upper Transition Zone.

Radicula Nasturtium-aquaticum Britten & Rendle, Journ. Bot. Brit. & For. **14**: 99. Water Cress

Occasional in streams in the Chaparral and Transition Zones.

Radicula obtusa Greene, Leafl. **1**: 113.
Bluff Lake, *Mrs. H. E. Benton.*

Barbarea othoceras Ledeb. Fl. Ross. **1**: 114. Winter Cress
Frequent along stream banks in the Upper Chaparral and Transition Zones.

Dentaria californica Nutt.; T. & G. Fl. **1**: 88.
Occasional in cañon bottoms in the Lower Chaparral Zone. Cold Creek and Waterman Cañons.

Arabis arcuata Gray, Proc. Am. Acad. **6**: 187.
Occasional on dry hills in the Upper Transition Zone.

Arabis Parishii Wats. Proc. Am. Acad. **22**: 468.
Locally abundant on a dry, stony slope, Bear Valley, the type station.

Arabis perennans Wats. Proc. Am. Acad. **22**: 467.
Occasional in dry soil in the Transition Zone.

Arabis perfoliata Lam. Dict. **1**: 219.
Occasional near streams in the Chaparral and Transition Zones.

Arabis platysperma Gray, Proc. Am. Acad. **6**: 519.
Occasional on dry hills in the Upper Transition and Canadian Zones.

Arabis repanda Wats. Proc. Am. Acad. **11**: 122.
Occasional on dry hills in the Upper Transition and Canadian Zones.

Streptanthus bernardinus Parish, comb. nov. *Agianthus bernardinus* Greene, Leafl. **1**: 328.
Common on dry hillsides in the Transition Zone.

Caulanthus amplexicaulis Wats. Proc. Am. Acad. **17**: 364.
Common on dry hillsides in the Lower Transition Zone.

Caulanthus crassicaulis Wats. var. *glaber* Jones, Zoe **4**: 266.
Frequent in the Upper Piñon Zone (Cushenberry cañon) and extending to the upper end of Bear Valley.

Thelypodium stenopetalum Wats. Proc. Am. Acad. **22**: 468.
Among Artemesia shrubs, in subalkaline soil, Bear Valley, the type station.

CRASSULACEAE

Dudleya bernardina Britton, Bull. N. Y. Bot. Gard. **3**: 19.
Common in crevices of rocks and in stony soil, in the Lower Chaparral Zone; the type from Waterman Cañon.

Sedum obtusatum Gray, Proc. Am. Acad. **7**: 342.
Locally abundant on rocks, near the Quarry, Mill Creek Cañon, in the Lower Chaparral Zone.

Sedum spathulifolium Hook. Fl. Bor. Am. **1**: 227.
On rocks near Big Meadows, in the Canadian Zone, *Wright.*

SAXIFRAGACEAE

Parnassia cirrata Piper, Eryth. **7**: 128.
Gilman's Cañon, Upper Transition Zone, the type station.

Lithophragma intermedia Rydb. N. A. Fl. **22**: 88.
Common on damp shady banks in the Upper Chaparral Zone.

Lithophragma scabrella Greene, Eryth. **3**: 102.
On a damp shady bank, Deep Creek, in the Lower Transition Zone.

Lithophragma triloba Rydb. N. A. Fl. **22**: 87.
Occasional on damp shady banks in the Upper Chaparral Zone.

Lithophragma tripartita Greene, Eryth. **3**: 102.
Occasional on gravelly slopes, in open pine forest, Bear Valley.

Heuchera elegans Abrams, Bull. S. Cal. Acad. **1**: 67.
Fredalba Park, Lower Transition Zone, *Grant.*

Heuchera hirsuta Rydb. N. A. Fl. **22**: 109.
Frequent on rocky hillsides, Snow Cañon, Hudsonian Zone, type station.

Heuchera Parishii Rydb. N. A. Fl. **22**: 109.
Abundant among rocks about Mill Creek Falls (type station), in the Upper Transition Zone.

Boykinia rotundifolia Parry; Gray, Proc. Am. Acad. **13**: 371.
Abundant along the borders of streams in the Lower Chaparral Zone; type region.

Saxifraga californica Greene, Pitt. **1**: 286.
Occasional on damp banks in the Lower Chaparral Zone. Early spring.

Ribes cereum Dougl. Trans. Hort. Soc. Lond. **7**: 512.
Frequent on dry slopes, Holcomb Valley, in the Upper Transition Zone.

Ribes hesperium McClatchie, Eryth. **2**: 79.
Frequent in cañons in the Lower Chaparral Zone.

Ribes hesperium McClatchie var. *amarum* Parish, comb. nov. *R. amarum* McClatchie, Eryth. **2**: 79.
Frequent with the species, with which it is well connected by intermediate forms.

Ribes nevadense Kellogg, Proc. Cal. Acad. **1**: 63.
Frequent on rich slopes in the Upper Chaparral and Lower Transition Zones.

Ribes Roezli Regel, Gartenfl. **28**: 226.
On rich banks, Mill Creek Cañon, Upper Transition Zone.

PLATANACEAE

Platanus racemosa Nutt. N. Am. Syl. **1**: 47. **Sycamore**
Occasional along streams in the Lower Chaparral Zone.

ROSACEAE

Sericotheca concolor Rydb. N. A. Fl. **22**: 264.
Occasional in rocky places in the Upper Transition, Canadian and Hudsonian Zones.

Amelanchier alnifolia Nutt. Jour. Acad. Philad. **7**: 22. *A. venulosa* Greene, Pitt. **4**: 21.
Abundant on dry hills in Bear Valley in the Upper Transition, and occasional in Cushenberry Cañon in the Piñon Zone.

Heteromeles arbutifolia Roemer, Syn. Monog. **3**: 105. **Christmas Berry**
Cañons and hillsides in the Lower Chaparral Zone.

Horkelia bernardina Rydb. N. A. Fl. **22**: 273.
Frequent on the banks of streams in the Upper Chaparral and Transition Zones; type region.

Horkelia Wilderae Parish, Bot. Gaz. **38**: 460.
Barton Flats in the Upper Transition Zone, *Mrs. Wilder*. Known only from the type locality.

Ivesia argyrocoma Rydb. Mem. Dep. Bot. Col. Univ. **2**: 144.
Common in dry meadows, Bear Valley, type locality.

Ivesia (*Stellariopsis*) *santolinoides* Gray, Proc. Am. Acad. **6**: 531.
Frequent on dry flats in Bear Valley and Lower Holcomb Valley.

Potentilla (*Argentina*) *Anserina* Huds. var. *concolor* Ser. in DC. Prodr. **2**: 582.
Moist flats, Bear Valley.

Potentilla biennis Greene, Fl. Franc. **1**: 65.
Borders of Baldwin Lake, Bear Valley. Bluff Lake, *Miss Pettibone*.

Potentilla comosa Rydb. N. A. Fl. **22**: 316.
Bear Valley, type station, acc. Rydb. l. c.

Potentilla Hallii Rydb. Bull. Torr. Club **28**: 176.
San Bernardino Mountains acc. Rydb. N. A. Fl.

Potentilla lasia Rydb. N. A. Fl. **22**: 314.
Bear Valley, type station, acc. Rydb. l. c.

Potentilla Wheeleri Wats. Proc. Am. Acad. **11**: 148.
Common on flats in Bear Valley.

Drymocallis cuneifolia Rydb. Mem. Dep. Bot. Col. Univ. **2**: 204.
Green Lead, Transition Zone. Known only from the type specimen.

Drymocallis Hanseni Rydb. Mem. Dep. Bot. Col. Univ. **2**: 200.
San Bernardino Mountains, acc. Rydb. N. A. Flora.

Drymocallis monticola Rydb. N. A. Fl. **22**: 370.
Common near streams in the Upper Chaparral and Lower Transition Zones.

Drymocallis reflexa Rydb. Mem. Dept. Bot. Col. Univ. **2**: 376.
Occasional in cañons of the Lower Chaparral Zone.

Drymocallis viscida Parish, Bot. Gaz. **38**: 460.
Hudsonian Zone. Snow Cañon (type) and Vivian Creek, *Grant*.

Drymocallis wrangelliana Rydb. Mem. Dept. Bot. Col. Univ. **2**: 201.
Occasional on dry banks in the Lower Chaparral Zone.

Fragaria californica C. & S. Linnaea, **2**: 30.
Occasional on shady banks in the Lower Transition Zone.

Geum macrophyllum Willd. Enum. **1**: 557.
Occasional in meadows in the Transition Zone.

Agrimonia gryposepala Wallr. Beitr. Bot. **1**: 49.
Locally abundant on stream banks, Potato Cañon, in the Upper Chaparral Zone.

Adenostoma fasciculatum H. & A. Bot. Beech. 139. Chamise
Covering in a dense pure stand most of the hillsides in the lower part of the Lower Chaparral Zone.

Purshia glandulosa Curran, Bull. Cal. Acad. **1**: 153.
Frequent on dry slopes in the Lower Piñon Zone.

Cercocarpus Douglasii Rydb. N. A. Fl. **22**: 421.
Abundant in dry washes, and on Lower hillsides in the Chaparral Zone.

Cercocarpus ledifolius Nutt; T. & G. Fl. **1**: 427.
Abundant in cañons and on flats in the Upper Transition Zone.

Rubus leucodermis, Dougl.; T. & G. Fl. **1**: 454. *Melanobatus bernardinus* Greene; Leafl. **1**: 244. Raspberry

Frequent on dry hills in Mill Creek Cañon, Upper Transition Zone.

Rubus parviflorus Nutt. Gen. **1**: 308.

Frequent in rich soil in the Lower Transition Zone.

Rubus vitifolius C. & S. Linnaea **2**: 10. Blackberry

Occasional in cañons in the Lower Chaparral Zone.

Prunus demissa Walp. Rep. **2**: 10.

Occasional, in groups, on cañon sides in the Upper Chaparral Zone.

Prunus emarginata Walp. var. *mollis* Dougl.; Hook. Fl. Bor. Am. **1**: 169. *Cerasus aridus* Greene, Proc. Biol. Soc. Wash. **18**: 57.

Frequent along streams running into Bear Valley, Upper Transition Zone.

LEGUMINOSAE

Pickeringia montana Nutt.; T. & G. Fl. **1**: 389.

Rare on shrubby hillsides, City Creek road, in the Upper Chaparral Zone.

Lupinus Breweri Gray, Proc. Am. Acad. **6**: 334.

On gravelly flats, Bear Valley.

Lupinus concinnus Agardh, Syn. 6, t. 1.

Occasional in sandy soil in the Transition Zone.

Lupinus confertus Kellogg, Proc. Cal. Acad. **2**: 192.

Abundant in dry meadows and on benches in Bear Valley.

Lupinus cystoides Agardh Syn. 18.

Abundant along streams and in springy places in the Chaparral and Transition Zones.

Lupinus formosus Greene, Fl. Franc. 42.

Common on dry ridges in the Lower Transition Zone.

Lupinus Grayi Wats. Proc. Am. Acad. **11**: 126.

On rocky hills, Bear Valley.

Lupinus Sitgreavesii, Wats. Proc. Am. Acad. **8**: 527.

Bluff Lake, *Miss Nora Pettibone.*

Lupinus sparsiflorus Benth. Pl. Hartw. 303.

Occasional on bushy hillsides in the Lower Chaparral Zone.

Lupinus Stiveri Kellogg, Proc. Cal. Acad. **2**: 192, f. 58.

A few plants on a rocky point opposite Dobbins Ranch, Lower Transition Zone. Probably now extinct.

Lupinus truncatus Nutt. Hook. & Arn. Bot. Beech. 336.

Occasional in cañons in the Lower Chaparral Zone.

Vicia americana Muhl, var. *truncata* Brewer; Brew. & Wats. Bot. Cal. **1**: 158.

Frequent on banks in the Lower Transition Zone.

Lathyrus laetiflorus Greene, Eryth. **1**: 106. Wild Sweet Pea

Frequent, clambering over bushes, in the Lower Transition Zone.

Glycyrrhiza glutinosa Nutt.; T. & G. Fl. **1**: 298.

Whiskey Spring, Cushenberry Cañon, Lower Piñon Zone.

Amorpha californica Nutt. T. & G. Fl. **1**: 306.

Frequent in the Chaparral, Lower Transition and Piñon Zones.

Hosackia americana Piper, Contrib. Nat. Herb. **11**: 366.

Occasional on dry banks in the Chaparral and Transition Zones.

Hosackia argyraea Greene, Bull. Cal. Acad. **1**: 184.

Frequent on dry hills in Holcomb Valley, and at Rose Mine.

Hosackia crassifolia Benth. Linn. Trans. **17**: 365.

Frequent in dry soil in the Transition Zone.

Hosackia glabra Torr. Bot. Wilkes Exped. 274.

Abundant on dry hills in the Lower Chaparral Zone.

Hosackia grandiflora Benth. Linn. Trans. **17**: 366.

Frequent on dry slopes in the Lower Transition Zone.

Hosackia nevadensis Parish, comb. nov. *H. decumbens* var. *nevadensis* Wats. in Brew. & Wats. Bot. Cal. **1**: 138.

Frequent on stony and rocky banks in the Upper Chaparral and Lower Transition Zones.

Hosackia oblongifolia Benth. Pl. Hartw. 305.

Occasional in wet places in the Lower Chaparral Zone.

Hosackia strigosa Nutt.; T. & G. Fl. **1**: 326.

Abundant on dry banks in the Lower Chaparral, and less frequent in the Transition Zone.

Hosackia Torreyi Gray, Proc. Am. Acad. **8**: 625.

Frequent in wet places in the Transition Zone.

Trifolium involucratum Willd. Spec. **3**: 172.

Frequent in wet meadows and by streams in the Chaparral and Transition Zones.

Trifolium longipes Nutt.; T. & G. Fl. **1**: 314.

Frequent in meadows, Bear Valley.

Trifolium microcephalum Pursh, Fl. **2**: 478.

Occasional in the Lower Chaparral Zone.

Trifolium monanthum Gray var. *grantianum* Parish, comb. nov. *T. grantianum* Heller, Muhl, **1**: 136.

Frequent on wet banks in the Upper Transition and Canadian Zones. Type from Vivian Cañon.

Trifolium Rusbyi Greene, Pitt. **1**: 5.

In meadows, Bear Valley.

Trifolium tridentatum Lind. Bot. Reg. t. 1070.

Frequent in cañons in the Chaparral Zone.

Trifolium variegatum T. & G. Fl. **1**: 317.

Frequent along streams in the Lower Chaparral Zone.

Oxytropis oreophila Gray, Proc. Am. Acad. **20**: 3.

Summit of San Gorgonio Mountain, *Wright*, *Mrs. Wilder;* type station.

Astragalus bicristatus Gray, Proc. Am. Acad. **19**: 75.

Dry flats in Bear and Holcomb Valleys, Upper Transition Zone, type region.

Astragalus lectulus Wats. Proc. Am. Acad. **22**: 471.

On gravelly flats, Bear Valley; Rose Mine.

Astragalus leucolobus Jones, Zoe **4**: 270.

Bear Valley, on stony slopes about Baldwin Lake (type station) and the Reservoir.

Astragalus Parishii Gray, Proc. Am. Acad. **19**: 75.

Common on gravelly hills in the Transition Zone.

GERANIACEAE

Geranium caespitosum James, Long's Exped. **2**: 3.
Rare in cañons between Bear Valley and Bluff Lake.
Geranium pyrenaicum Burm. f. Sp. Geran. 27.
Vivian Trail, San Gorgonio Mountain, at 7000 ft. alt. *Grant*, the only Californian collection.
Geranium Richardsonii Fisch. & Trautv. Ind. Sem. Hort. Petrop. **4**: 37.
Frequent in open pine forest in the Lower Transition Zone.

LINACEAE

Linum Lewisii Pursh, Fl. 210.
Frequent in dry soil in the Transition Zone.

EUPHORBIACEAE

Chamaesyce albomarginata Small, Fl. Se. U. S. 1333.
Frequent in red clay soils in the Lower Chaparral Zone.
Chamaesyce ocellata Millsp. Field Mus. Publ. Bot. **2**: 410.
Rare, Waterman cañon at about 2000 ft. alt.
Chamaesyce hirtula Millsp. Field Mus. Publ. Bot. **2**: 409.
Occasional in dry soil in the Transition Zone.
Tithymalus Palmeri Parish, comb. nov. *Euphorbia Palmeri* Engelm. in Wats. Bot. Cal. **2**: 75.
Frequent on dry ridges in the Transition Zone.

CALLITRICACEAE

Callitriche palustris Linn. Sp. Pl. 992.
Submerged in still pools of streams; Talmadge's Mill and Bear Valley.

ANACARDIACEAE

Rhus diversiloba T. & G. Fl. 1: 218.
Frequent in cañons in the Chaparral Zone.
Rhus ovata Wats. Proc. Am. Acad. **20**: 358.
Occasional in cañons in the Lower Chaparral Zone.

ACERACEAE

Acer bernardinum Abrams, Torreya 17: 219.
Mill Creek, at the forks of Snow Cañon (type station) and near Forest Home.
Acer macrophyllum Pursh, Fl. 267. Maple
Occasional on the banks of streams in the Chaparral Zone. Twenty feet high but not arborescent in habit.
Acer Negundo Linn. var. *californicum* Sarg. Gard. & For. **4**: 148. Box Elder
Locally abundant along Potato and Edgar Cañons in the Lower Transition Zone.

RHAMNACEAE

Rhamnus californica Esch. Mem. Acad. St. Petersb. VI, **10**: 285.
Frequent along the sides of cañons in the Upper Chaparral Zone.
Rhamnus californica Esch. var. *tomentella* Brew. & Wats. Bot. Cal. **1**: 101.
With the species but much less abundant.
Rhamnus crocea Nutt.; T. & G. Fl. **1**: 261.
Infrequent on dry hills in the Lower Chaparral Zone.
Ceanothus cordulatus Kellogg, Proc. Cal. Acad. **2**: 124, t. 39.
Abundant, forming dense thickets, on open slopes in the Upper Transition Zone.
Ceanothus crassifolius Torr. Pac. R. Rept. **4**: 75.
Frequent on dry hillsides in the Lower Chaparral Zone.
Ceanothus cuneatus Nutt.; T. & G. Fl. **1**: 267.
Occasional on bushy slopes in the Lower Chaparral Zone.
Ceanothus divaricatus T. & G. Fl. **1**: 266. California Lilac
Abundant on cañon sides in the Lower Chaparral Zone.
Ceanothus Greggii Gray, Pl. Wright, **2**: 28.
Frequent on bushy slopes and ridges in the Piñon Zone, extending to Gold Hill, at the upper end of Bear Valley.
Ceanothus integerrimus H. & A. Bot. Beechey 329.
Frequent on bushy slopes in cañons of the Upper Chaparral Zone.
Ceanothus tomentosus Parry, Proc. Davenp. Acad. **5**: 190.
Locally abundant about the mouth of Mill Creek Cañon, in the Lower Chaparral Zone.

VITACEAE

Vitis girdiana Proc. Soc. Prom. Agr. Sci. 1887, 59. Wild Grape
Frequent near streams and springs in the Lower Chaparral and Lower Piñon Zones.

CHERANTHODENDRACEAE

Fremontia californica Torr. Pl. Frem. 5, t. 2.
Abundant in cañons in the Piñon Zone.

MALVACEAE

Sidalcea Hickmani Greene var. *Parishii* Robins, Syn. Fl. 1, pt. 1: 307.
Dry mountain side above Seven Oaks, type station. Not otherwise known.
Sidalcea malvaeflora Gray, Proc. Am. Acad. **21**: 409.
Frequent in meadows in the Lower Transition Zone.
Sidalcea pedata Gray, Proc. Am. Acad. **22**: 288.
Frequent in meadows in Bear Valley, type station. Not otherwise known.
Malvastrum Davidsonii Robins, Syn. Fl. 1, pt. 1: 312.
Infrequent on dry slopes, Cushenberry Cañon, in the Upper Piñon Zone.

ELATINACEAE

Elatine americana Arn. Edinb. Jour. Nat. & Geog. Sci. **1**: 431.
Rare, in shallow water and on the borders of it, in the Transition Zone.

CISTACEAE

Helianthemum scoparium Nutt.; T. & G. Fl. **1**: 152.
Abundant on dry hillsides in the Lower Chaparral Zone.

VIOLACEAE

Viola blanda Willd. Hort. Berol. t. 24. White Violet
Frequent about cold springs and bogs in the Transition and Canadian Zones.

Viola chrysantha Hook. Ic. t. 49. Yellow Violet
Abundant in meadows in Bear Valley, and occasional elsewhere in the Transition Zone.

Viola obliqua Hill. Hort. Kew. 316, t. 12.
In meadows at Seven Oaks, Upper Transition Zone.

Viola canina Linn. var. *adunca* Gray, Proc. Am. Acad. **8**: 377. Blue Violet
Frequent on moist banks in the Transition Zone.

Viola praemorsa Dougl.; Lindl. Bot. Reg. t. 1254.
Frequent in pine forest in the Transition Zone.

LOASACEAE

Mentzelia albicaulis Dougl.; Hook. Fl. Bor. Am. **1**: 222.
Common in dry soil in the Piñon Zone, and also in Bear Valley.

Mentzelia davidsoniana Parish, comb. nov. *Acrolasia davidsoniana* Abrams, Bull. Torr. Club **32**: 538.
Common in dry soil in the Piñon, and in Bear Valley in the Upper Transition Zone.

Mentzelia dispersa Wats. Proc. Am. Acad. **11**: 115.
Occasional in dry soil in the Lower Chaparral Zone.

Mentzelia laevicaulis T. & G. Fl. **1**: 535.
Occasional in dry washes in the Lower Chaparral Zone.

Mentzelia micrantha T. & G. Fl. **1**: 535.
Occasional in dry soil in the Lower Chaparral Zone.

DATISCACEAE

Datisca glomerata B. & H. Gen. Pl. **1**: 845.
Occasional on the banks of streams in the Lower Transition Zone.

(*To be continued*)

BOOKS AND CURRENT LITERATURE

Experimental Results in Plant Physiology.—A recent book[1] offers to "senior students and investigators" some of the results of experimentation "in a few of those branches of plant physiology which are at present attracting attention." The subjects included are: Carbohydrates in the plant kingdom in relation to photosynthesis, respiration and translocation; Pectic substances; Osmotic pressure and permeability of organic septa, including protoplasm; Electrical conductivity of plant tissues; Functions of wood; Plant oxidases and their relation to pigmentation, pathology and technology. The number of titles included in the bibliography totals nearly four hundred and "a small amount of hitherto unpublished work has also been included."

Turning first to the selection of material, it should be noted that the author does not present these subjects from a conviction that they are the most important of the recent work in plant physiology. He has restricted himself to those enumerated "on account of his first-hand knowledge of many of the processes employed." The purpose is excellent and, although the lack of unity evident in the table of contents might perhaps be adjudged undesirable, the readers for whom the book is intended will undoubtedly not consider this as a serious fault.

It is difficult, however, to see the value of that portion of Chapter V that deals with the quantitative laws of osmotic pressure. Its presence is not in keeping with the author's general purpose and is not to be expected after reading that "matter already to be found in text books has been almost entirely excluded." It is not an instructive discussion of the quantitative laws of osmotic pressure because it is limited to the statement of but one expression (applicable only to ideal solutions) and to the enumeration of the assumptions necessary to derive the van't Hoff equation from it. Even in this narrow field it is incomplete and misleading. The reasoning upon which the equation is based is omitted and with it the educational value of the expression itself. The equation is stated to be "the most generally applicable," whereas it can only apply to an ideal case, and is accordingly of so exceedingly restricted an application that it is of little value in biological calculations. The assumptions made in its formation are also incompletely stated, for they include, besides those enumerated, the requirement that the vapor be a perfect gas. Although the attempt to put osmotic pressure on a more rational basis than it has in biology at present is commendable, the author's space is entirely inadequate for this purpose. The definition of osmotic pressure is incomplete, for it takes no account of the quantitative difference in the effects of pressure upon the solvent and the solution, and the discussion of the nature of osmosis leaves the reader with the impression that there is must less definite information on the subject than is actually the case.[2]

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[1] Atkins, W. R. G. Some Recent Researches in Plant Physiology, pp. 328 figs. 28. London, Whittaker and Company, 1916 ($2.40).

In his presentation the author has included a large amount of the graphical and numerical results of the researches considered. About these results he has built the discussion, which consists chiefly of a critical comparison of the conclusions and opinions of the various investigators, and this necessitates in many cases a consideration of the methods employed. The point of view throughout is that of the experimentor and little attention is paid to the effect of these results upon the more general aspects of plant physiology.

The discussion is excellent and by its very form should stimulate students who are attempting to acquire a power of critical comparison of experimental results, although the author at times employs expressions that seem to strengthen an argument beyond its proved value. This overstatement appears to be due to a desire not to undervalue results whose experimental details he does not undertake to criticize, for in the fields in which he has worked his statements are less emphatic. The criticisms of methods are usually judicial and are a valuable feature of the book. Unfortunately the physics or chemistry underlying the methods is at times overlooked, and, in his desire not to undervalue, the author occasionally seems to overvalue.

The book is well written, very readable and well arranged, and it is to be hoped that its reception will stimulate the presentation of other phases of plant physiology in a similar manner.—H. E. PULLING.

PROTHALLIA OF LYCOPODIUM.—An interesting and important botanical discovery—that of the first prothallia of *Lycopodium* to be found in

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[2] One of the best accounts of the present state of knowledge on this subject and that of osmotic pressure is to be found in Washburn's Physical Chemistry (Washburn, Edward W., An Introduction to the Principles of Physical Chemistry. New York, 1915).

America, has recently been announced.[1] The prothallia were growing in the vicinity of Marquette, Michigan, in sandy soil, and seventeen of them were found on an area 10 meters square. In all five species are represented: *L. complanatum*, *L. annotinum*, *L. clavatum*, *L. obscurum* and *L. lucidulum*, with twenty-one prothallia and fifty sporelings. Prothallia of the last two species listed are new. The fact that the discovery was made by a correspondence student of botany makes it a unique one. Heretofore material for the study of prothallia of *Lycopodium* has been obtainable practically only from Bruchmann of Germany, whose studies are well known.

In the same journal Chamberlain describes prothallia and sporelings of three New Zealand species of *Lycopodium: L. laterale, L. volubile* and *L. scariosum.*[2] The prothallium of the first mentioned species is green and leafy, and the protocorm-protophyll stage is present in the development of the embryo; those of the last two species are subterranean and lack the protocorm stage in their embryogeny. The paper contains, in addition to descriptions of the prothallia and anatomical study of the sporophyte, a concise historical résumé of the work that has been done on prothallia of *Lycopodium*.—J. G. Brown.

Recent Work on the Gnetales.—The Gnetales have recently become adequately known, thanks to the supply of material which is now available. Following the work of Land on *Ephedra* in 1904 and 1907, Lignier, Pearson and Thompson have cleared up the chief features in the morphology of the other two genera of the order. Thompson's papers on *Ephedra* and *Gnetum*[3] bring anatomical data to bear on the vexed problem of the relationships of the order, and this author comes to the conclusion that "The angiosperms have been derived from ancestors very much like modern Gnetales. In fact the genus *Gnetum* should probably be classed with angiosperms."—M. A. Chrysler.

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[1] Spessard, E. A. Prothallia of *Lycopodium* in America. Bot. Gaz. **63**: 66–76. 1917.

[2] Chamberlain, C. J. Prothallia and Sporelings of Three New Zealand Species of Lycopodium. Bot. Gaz. **63**: 51–65. 1917.

[3] Thompson, W. P. Anatomy and Relationships of the Gnetales. I. Ephedra. Annals of Bot. **26**: 1077–1104, pls. 94–97. 1912.

Ibid. The Morphology and Affinities of *Gnetum*. Amer. Jour. Bot. **4**: 135–184. 1916.

NOTES AND COMMENT

The growing economic importance of tropical countries, especially those of Latin America, has focused the attention of scientists on the research problems connected with the development of the natural forest resources of those countries. The Amazon forest region of South America covers an area of approximately 1,600,000 square miles. The heavily forested portion of the Indo-Malayan region, comprising the Philippines, Borneo, Sumatra, Malay Peninsula and parts of Burma, has an estimated area of not less than 500,000 square miles, which is nearly that of the United States. Recent investigations in the Philippines and Borneo have shown that the forests of these regions contain suitable kinds and sufficient quantities of timber to supply the needs of a general market, and recent lumbering activities in the Philippines, Borneo and Sumatra have proved that their timbers, with modern logging and milling methods, can be placed on the market cheaply and in large quantities. Recent investigations in at least two forest regions of South America show that, like the Indo-Malayan region, soft and medium hard woods compose 50 per cent and more of the stands.

The School of Forestry at Yale has established courses in tropical forestry with the hope of drawing students from South America who will on graduation return to their respective countries and be the means of awakening their governments to a realization of the usefulness and conservation of the forest resources. In connection with instruction the Forest School is planning investigative work along all lines of tropical forestry, and this will include ecological investigation. One phase of this work that is necessary to the proper development of forestry policies is the classification of the different kinds of forests.

If the work of ecologists and foresters in the Philippines has shown anything, it has demonstrated that there is a wrong conception of the nature and value of tropical forests. This is due entirely to the fact that there has not been a proper analysis of the forest vegetation. So far, such analyses have usually been qualitative. What is needed is a quantitative analysis. Not only is it necessary to show the number of individuals of each species, but to arrange them in diameter classes. By this means one arrives, by the process of elimination, at the composition of the dominant species. Such a study is only a modification of the quadrat or transect method on a large scale, covering acres in extent instead of small areas. In a word it is the cruising method of

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the forester. Huber estimates the number of speci[illegible]d plants in the Amazon basin as not more than 20,000, of which [illegible] are woody plants. Of these 10,000 woody forms he states that not [illegible] than 2500 can be considered as trees. The number of dominant [illegible] that form the canopy of the dense forest would be much less. It [illegible] that there is a possibility of dividing this poorly known region, which [illegible] part of the so-called tropical rain forest formation, into a number [illegible] different formations, just as the coniferous forests of the west are so di[illegible]led, and of giving them the names of dominant species or genera.

It is believed that many of the problems in the study of vegetation in the temperate regions cannot be successfully solved until we have more and better knowledge of tropical vegetation. We are now interpreting temperate and tropical vegetation in terms of temperate conditions. With a better knowledge of the vegetation in the regions where ecological conditions reach their optimum, I am convinced that many of our "*provincial temperate ideas*" about ecology will be greatly modified.—H. N. WHITFORD.

In the recently issued eighth volume of the Bulletin of the New York Botanical Garden Mr. Percy Wilson has contributed a paper on the Vegetation of Vieques Island, which lies between Porto Rico and the islands recently acquired by the United States from Denmark. The word vegetation is not used in the title of this paper in its commonly accepted sense, since the text gives only a brief page to that subject and is mainly devoted to a list of the flora. The energetic explorations of the New York Botanical Garden are adding rapidly to our knowledge of the flora of the smaller as well as the larger of the West Indian islands, and it is to be hoped that this knowledge will soon be utilized in connection with further investigations of the vegetation of these islands.

Among the papers appearing in subsequent issues of The Plant World will be the following: Soil Temperatures as a Factor in Phytopathology, by Prof. L. R. Jones; The Beginnings and Physical Basis of Parasitism, by Dr. D. T. MacDougal; The Indicator Significance of Native Vegetation in the Determination of Forest Sites, by Mr. Clarence F. Korstian; The Adaptation of Truog's Method for the Determination of Carbon Dioxide to Plant Respiration Studies, by Mr. A. M. Gurjar; and The Interpretation and Application of Certain Terms and Concepts in the Ecological Classification of Plant Communities, by Dr. George E. Nichols.

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SOIL TEMPERATURES AS A FACTOR IN PHYTOPATHOLOGY

L. R. JONES

University of Wisconsin, Madison, Wisconsin

The correlation between climatic conditions and the occurrence of plant diseases is obvious to the most casual observer. This has always led the unscientific cultivator to blame the weather solely for his rusts and mildews. On the other hand, the mycologically-minded phytopathologist, whose first thought is naturally of the spore, needs frequent reminder of the fact, recently emphasized by Smith (1), that the most important, and the most complex problems for long-time research include the critical study of the relation of environment to parasitism.

The way the plant pathologist is forced to face these problems in practice was well illustrated in Wisconsin in 1915 and 1916. During these years we had under critical study two fungus diseases of commonest garden crops, viz., the late blight of the potato (*Phytophthora infestans*) and the yellows disease of the cabbage (*Fusarium conglutinans*) (2). Of these two summer seasons, 1915 was cool and moist and 1916 exceptionally hot and dry. In 1915 the late blight fungus, stimulated by the favoring weather, destroyed some millions of dollars worth of potatoes with the worst outbreak for at least a decade. As a result almost every lot of seed potatoes in the state carried the infection to the fields in 1916, yet the dry heat held the parasite so completely in check that the expert mycologist had to search the potato fields of the state with a magnifying glass to find a single incipient development of the disease. By way of contrast in 1915, alongside these sick potato fields in Wisconsin, the cabbage crop was everywhere vigorous, even on the worst Fusarium "sick"[1] soils whereas

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[1] *Fusarium conglutinans*, the soil parasite causing the disease known as cabbage yellows, persists indefinitely in infected fields so that ordinary crop rotations do not eliminate it. The growers term such lands "cabbage sick."

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under the dry heat of 1916 these same cabbage fields were swept by the yellows disease as if by fire.

Every phytopathologist can parallel such experiences. Temperature and moisture are, of course, the obvious variable factors. If, however, we are inclined to consider the problem simple we need but turn to Livingston's (3) recent attempt to work out the formulae involved in the physiological temperature indices for the study of plant growth. Livingston was thinking primarily of the higher plants only. The pathologist has to consider simultaneously the relation of these variable factors to the two organisms host and parasite. If we were to accept Livingston's conclusions as applicable to parasite as well as host and then try to work out the complex correlation curves we might well despair at the outset, or at least wait for the physiologist to blaze the way. Fortunately the terms seem simpler for some of the problems which are of most immediate interest to the phytopathologist. Thus, for at least two groups of seedling or root-invading parasites, certain smuts and Fusariums, slight variations in soil temperature at critical periods seem to be the deciding factors in possible parasitism. While problems involving root parasites are in general more difficult to define than those with aerial parts, in this particular type the advantages are with the former, since light and transpiration are largely eliminated as variables with roots, and moisture is more easily controllable than with parts exposed to the air.

Fusarium species. Gilman's (4) observations, at first in Wisconsin fields and later continued in greenhouse experiments with the soil organism *Fusarium conglutinans*, seem to show conclusively that its ability to induce the cabbage yellows disease is conditioned upon a soil temperature of 17° or above, and that it is powerless as a parasite at lower soil temperatures.

Tisdale (5), working in our greenhouses, has since shown similar limitations to hold for another Fusarium root disease, flax wilt, (*Fusarium lini*). Thus, in his experiments using badly infected soil, the flax developed normally when the soil temperature was held continuously below 15°C., but if the temperature rose for even one day above 16°C., infection occurred and the wilt followed.

Orton, discussing the potato plant in its relation to disease, has pointed out (6, 7) that the Fusarium wilt of the potato has a southern range as compared with the similar Verticillium wilt of the northern regions. Haskell of Cornell University (in correspondence) states that his studies lead him to the conclusion that "soil temperature is the most important limiting factor in the development of Fusarium wilt of potato in New York State."

Link (8) in connection with his physiological studies of two strains of Fusarium in their causal relation to tuber rot and vine wilt of potato finds that *F. oxysporum* has a higher optimum temperature than *F. trichothecoiodes* and concludes that this may explain the fact that the first is the cause of field wilt under warm soil conditions whereas the latter develops as a tuber rot under cooler storage temperatures.

Humphrey (9) working in the state of Washington concluded that the occurrence of the Fusarium tomato blight of the Pacific Northwest (*Fusarium orthoceros* and *F. oxysporum*) is conditioned upon high temperatures. While he recognizes as possible factors air temperature and winds in relation to transpiration, he concludes that it is when the soil temperature rises too near the optimum for the parasite that the disease results. He finds that these tomato parasites show infective powers at 18°C. (65° F.) and that their virulence increases with rise of temperature to their optimum 30°C. (86° F.). The writer (10) and Gifford (11) have recorded the association in Vermont of the Fusarium damping-off in coniferous seedlings with high soil temperatures.

These things, together with the prevalence of Fusarium root diseases in the southern states, seem to justify Wollenweber's generalization (12) that the root-invading Fusariums are warm soil organisms.

The smuts. The grain smuts constitute another group of parasites where facts of similar significance are available. With these the period of possible infection is limited to a brief stage in the early development of the host seedling. The possible influences of soil temperature upon host as well as parasite are, therefore, involved.

The results obtained by various investigators on the stinking smut of wheat (*Tillaetia tritici*), including Hecke (13) and Munerati (14) in Europe, Heald and Woolman (15) and Humphrey in America, point clearly to temperature of the soil at time of seed germination as a factor controlling infection. Humphrey (in correspondence) sums up the conclusions that "it seems now to be an established fact that soil temperatures of 0° to 5°C. are decidedly unfavorable to successful infection as are also temperatures higher than 22°C., with 15° to 22°C. as the optimum for the development of the smut." In accord with this conclusion the farmers of the Pacific Northwest are finding that "by sowing their winter wheat either very early (warm soil) or very late (cold soil) they can reduce the loss from smut to an almost negligible percentage." Munerati has pointed out similar variations of infection with date of planting spring wheats in Italy.

The writer's interest in the possible relation of soil temperature to infection with oat smut was first aroused in Vermont over twenty years ago (16) upon finding that the smut was less abundant in Vermont than in the western States even when heavily smutted seed was used, and he at that time attempted to secure comparative data as to soil temperatures during the germination period. This problem has received experimental treatment by several investigators including Brefeld (17), Tubeuf (18), and Hecke (13) in Europe and G. M. Reed and A. G. Johnson (correspondence) in America. While the results point clearly to soil temperature as an important factor they are not fully in accord, the variations being apparently in part at least dependent upon whether constant or variable temperatures are used.

Although it is only in these two groups of parasites that we have sufficient data to justify any generalization, there can be no doubt that further study will bring out constantly increasing evidence of the importance of soil temperature as influencing either the occurrence or severity of the attacks of soil parasites of other types.

Balls (19) has shown that Rhizoctonia can attack cotton at

20°C. but not at 33°. This suggests the possible importance of temperature as a factor in explaining the variation in experience with Rhizoctonia on the potato. Certainly there is a wide variety of potato-disease problems where we must know the relations of soil temperature to both host and parasite before we can fully understand them. And this holds true for parasites of the most diverse type. As illustrating this, one may consider the regional limitations in the occurrence of the two bacterial diseases of the potato, the brown rot (*Bacterium solanacearum*) and black leg (*Bacillus phytophthorus*). Both of these are distributed with the seed tuber hence have doubtless been introduced equally widely and very generally. The evidence seems conclusive, however, that in America the brown rot is practically confined to the south-eastern states, whereas the black leg is northern in its persistent occurrence. It is also of like import to note the increasing evidence that the myxomycete causing powdery scab (*Spongospora*) may be restricted to the northern limits of the potato belt by its limited temperature endurance. Again, I am at a loss to account for the curious fluctuations in the occurrence and degree of development of common scab (*Oospora*) which I have previously recorded (20) unless we admit soil temperature as an influential factor; and certain observations, both as to its relatively lesser development in Europe and as to its seasonal and regional variations in America, incline me to the theory that high soil temperatures at certain critical periods are essential to its serious parasitism. Perhaps the most puzzling problems in American potato pathology relate to the Colorado potato failures. Different observers have in turn attributed the trouble to Rhizoctonia, to Fusarium, and to degenerate seed stocks. Whatever may be the causal interpretation, all now seem agreed that high soil temperatures are an important condition influencing the development of these pathological results.

Examples could be further multiplied, but these will at least suffice to show the reason for the lively interest of phytopathologists in soil temperature problems. This is already leading such investigators in at least two of our universities, Wisconsin and

Cornell, to endeavor to perfect methods of securing data as to such temperatures under controllable experimental conditions.

In the earlier work at Wisconsin the endeavor was to grow the plants in greenhouse rooms of differing temperature. It is, however, almost impossible to maintain house temperatures within narrow enough limits for the results desired. Therefore, we have turned to the use of the constant temperature water jacket surrounding the culture pot or jar. Tisdale, in his work on the flax wilt to which reference has previously been made, adopted the simple method illustrated in figure 1, using a single culture jar sunken in a larger receptacle through which cool tap water trickled just rapidly enough to maintain the desired temperature. Wishing to secure simultaneously a series of constant temperatures we have since expanded this idea, under the supervision of R. E. Hartman, who is investigating the relation of soil temperatures to the development of tobacco and its infection with the root parasite *Thielavia basicola*. The essential method is illustrated in figure 2. In this way, Hartman has maintained fairly constant temperatures at points between

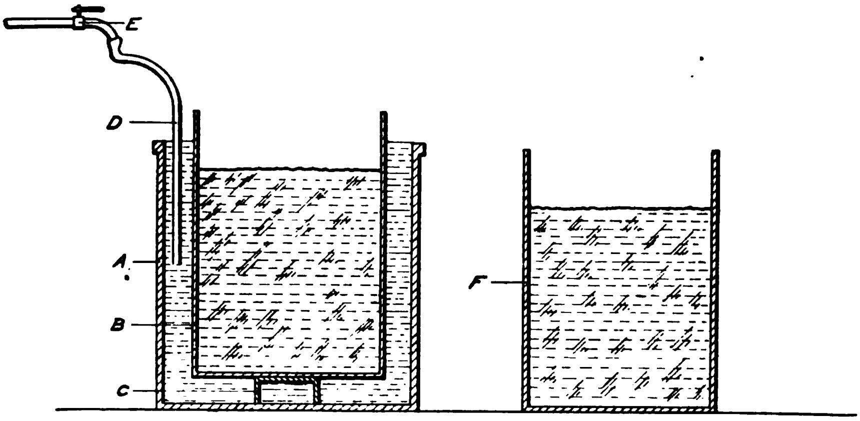

Fig. 1. Constant temperature culture jars. *A* is a large earthenware jar with a constant flow of tap-water entering through the tube *D*, regulated by the faucet *E*. *B* is a smaller glass jar resting on a support *C* and containing soil in which the experimental plants may be grown at approximately constant soil temperature. *F*, Control culture jar at room temperature.

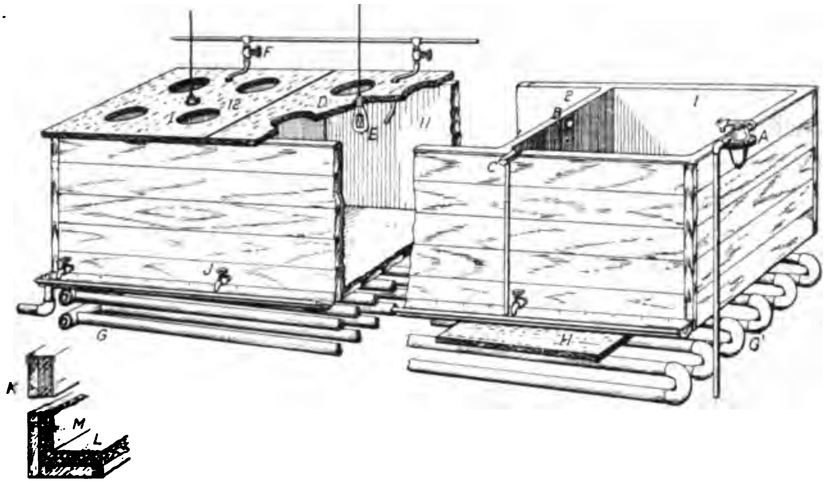

Fig. 2. Graduated temperature tank. This is installed on a greenhouse bench. It has 12 compartments (*1–12*), each of which can be held at a different constant temperature. Cold water flows into compartment *1* at *A* through a constant pressure valve. About one-fourth of the intake water is allowed to pass into compartment *2* through the hole *B* which is 2 inches below the top of the partition and another hole 8 inches below *B* (not shown in diagram). About ¾ overflows through the waste pipe *C*. The water passes similarly from compartment *2* to *3*, and from *3* to *4* with gradually elevated temperatures until in compartment *5* the temperature approximates that of the greenhouse. Compartments *6–12* are for graduated temperatures above that of the greenhouse. In these the water is static, the higher temperatures being regulated by four devices: first, an asbestos cover *D;* second, electric heating bulbs *E;* third, live steam pipes *F;* fourth, the regular steam heating system of the greenhouse of which the pipes at *G* lie as close as possible under compartment *12* and slope to a distance of 9 inches from the bottom of compartment *1* at *G'*. In addition a sheet of asbestos *H* is laid on the pipes at this lower end to check the radiation. Each compartment has a drain cock *J*. At lower left corner is sectional view to show detail of wall construction: *K*, 1 inch board; *L*, 1½ inch hair-felt; *M*, galvanized iron lining.

By proper regulation and manipulation during the past winter it has been possible to hold each compartment within a fluctuation of about 1° at temperatures as follows: compartment *1*, 5°C.; *2*, 9°; *3*, 13°; *4*, 16°; *5*, 19°; *6*, 21°; *7*, 23°; *8*, 26°; *9*, 29°; *10*, 32°; *11*, 36°; *12*, 40°. In each compartment were sunk 4 battery jars (*I*) filled with soil for the culture of the experimental plants essentially as illustrated in figure 1.

5° and 40°C. He will publish the final outcome later, but the results to date show that this method will yield data of much interest to the physiologist as well as the pathologist.

The satisfactory interpretation and practical application of such results is, however, dependent upon securing reliable and comparable field data over a wide range of territory, north, south, east and west. We, as phytopathologists, should therefore be ready to cooperate in any way practicable in the soil temperature survey which is being organized under the leadership of the Ecological Society of America. It should be a further stimulus in this endeavor that Russian plant pathologists have already inaugurated plans for a similar survey in their territory (21) and possibly international cooperation may follow any success in such national undertakings.

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THE BEGINNINGS AND PHYSICAL BASIS OF PARASITISM

D. T. MACDOUGAL

Desert Laboratory of the Carnegie Institution, Tucson, Arizona

A series of experiments for the purpose of determining the major conditions under which one seed-plant, ordinarily autophytic, might become parasitic upon another were begun at the Desert Laboratory in 1908. The method of making the preparations, the behavior of the xeno-parasites, and the absorbent relations of the enforced host and experimental parasite have been described by the author in various papers.[1]

In addition to the experimental tests several cases have been encountered in the field work from the Desert Laboratory in which Opuntias were seen established on *Parkinsonia*, *Acacia* and *Carnegiea* with the roots in nutritive contact with the tissues of the supporting plant and under such conditions that the sole supply of solution must have been received from the newly-found host.

An instance of this kind was encountered on March 15, 1913 when a field party found a sahuaro 57 miles southwest of the Desert Laboratory bearing near its summit an *Opuntia*, which was in all certainty *Opuntia Blakeana*, (probably equivalent to *O. phaeacantha*). During the course of cutting down the tree cactus for an examination of the relations of the two plants, a Papago Indian came up and showed the author the same species in the soil nearby, and he gave the native name as "*e'epa.*" It is identical with the *Opuntia* which has been found on *Carnegiea* in another instance.

The tree cactus was about 20 feet in height and bore two large lateral branches, while a third had been broken off near the summit of the trunk. A cavity had been formed in the trunk in the sinus formed by a branch, and this was heavily lined with callus and had a capacity of about a liter. The tangled mass of roots of the prickly pear completely filled the cavity holding together a compact mass of organic matter derived partly from the original tissue now decayed. Near one side of the root-mass, however, an active, strongly-growing whitish root a few millimeters in diameter had pushed through the callus walls and down into a crevice of the live cells of the *Carnegiea.* Its branches were spread out and were applied to the pale tissues of the host although no mechanical adhesion of any consequence was detected. It was clear however that some degree of absorption would be possible, and the appearance of rapid growth on the part of the *Opuntia* was one which could result only from a supply of material.

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[1] See MacDougal, D. T., Induced and Occasional Parasitism. Bull. Torr. Bot. Club. **38**: 471. 1911.

An Attempted Analysis of Parasitism. Bot. Gaz. **52**, 249, 1911.

The case was one of undoubted parasitism, and moreover the dependent in this case had been in this position for an extended period since the clump of roots was heavy and seven main stems of the cylindrical form characteristic of the basal part of the plant were found, each of which had at times produced flattened joints. Some were now in a shrivelled condition and doubtless many had been formed in the previous years for which an adequate supply of solution was not available and they had been cast off.

Dr. W. B. MacCallum has recently discovered a similar case of parasitism of an *Opuntia* on a sahuaro on the lands of the company engaged in guayule culture at Continental, 30 miles south of Tucson. An *Opuntia* with many joints was established in the angle formed by a branch and the main stem. As the parasite was not more than 2 meters from the ground it could be readily photographed and examined. It was not disturbed, however. All of the tree cacti here had been bored by the "carpinteros" or woodpeckers, and it is probable that the seed from which this plant originated had been deposited in a cavity made by these birds (see fig. 1). The sahuaro, which had an age of nearly two centuries, stood in the rectangular mass of stones supposedly marking a prehistoric human grave.

These occurrences raise interest in the relative conditions which must prevail in two plants so that one becomes parasitic on the other. The earlier experimental studies of the author led him to conclude that a necessary condition of parasitism was a higher osmotic concentration of the species which could become parasitic.

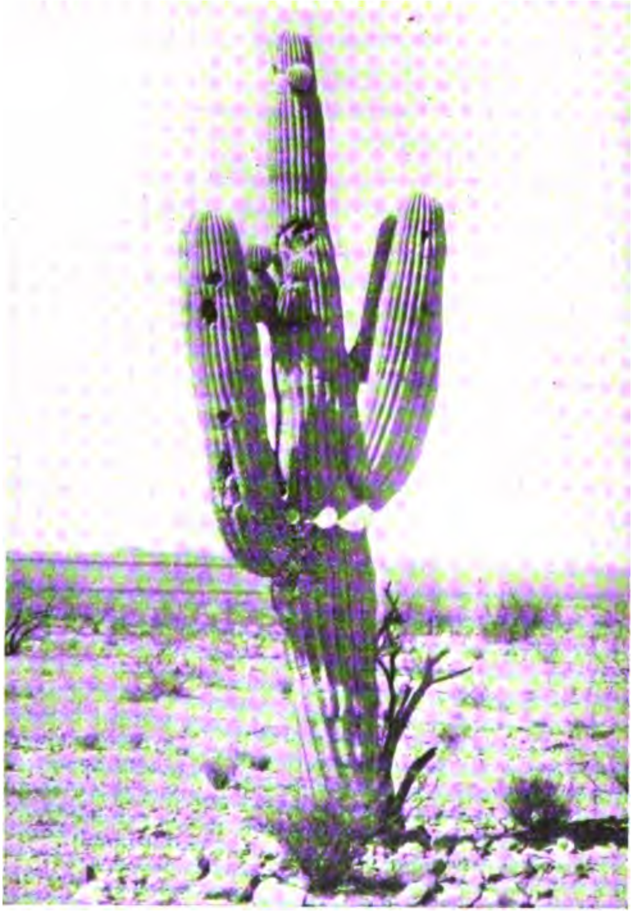

Fig. 1. Sahuaro (*Carnegiea gigantea*) growing on prehistoric human grave near Continental, Arizona. *Opuntia* growing as a parasite in axis of lowermost branch.

Harris and Lawrence have carried out an extensive investigation of the problem on Loranthaceous parasites in the Jamaican rain forests, and in a paper now in press have shown that in case of plants growing under these conditions the parasite is generally but not invariably characterized by a higher osmotic concentration of its fluids. They also show that on theoretical grounds higher osmotic pressure of the tissue fluids is not a necessary prerequisite of successful parasitism in the case of a species living under natural conditions.[2]

That the absorbing organs of a plant might withdraw liquids from tissues of another plant, the sap of which had a higher concentration, is also to be concluded from the results of recent work on imbibitional phenomena at the Desert Laboratory.

Extended series of measurements established the fact that a mixture consisting of 90% or more of agar and 10% or less of protein, albumen, gelatine, tyrosin or cystin, takes up water in a manner remarkably parallel to that of pieces of tissue of living plants. This similarity is regarded as more than a coincidence. The plant protoplast consists largely of carbohydrates of the pentosan group, with which are mixed varying proportions of nitrogenous material which may be in the form of protein, amino-acids, etc. Such a mixture would have identical relations to water either as swelling plates in the laboratory, or as water-absorbing sheets or strands of colloid in the cell.

A number of agencies or conditions are found to affect the total amount of water which may be taken up by this "plant-colloid" mixture. Thus, for example, nearly all of such mixtures absorb slightly more water in acidified solutions than in alkaline, and many times as much from neutral as from either acid or alkaline solutions. Some salts in the solution increase imbibition and some lessen it.

These generalizations rest upon measurements made by the following method: Small sections of dried plates of a mixture of "plant-colloids" were placed in trios in glass dishes into which various solutions might be poured. Triangular pieces of thin glass were laid on these pieces. The swinging vertical arm of an auxograph rested in a socket in the middle of this plate. When the entire preparation was in readiness and the pen at the other end of the compound lever was marking properly on the ruled paper of a revolving cylinder, the solution was poured into the dish. The rate, course and amount of expansion was recorded by an inked line. (See Mem. N. Y. Botan. Garden, 6, pp. 5–26, 1916, for a description of instrument.)

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[2] Report Dept. Bot. Res. Carnegie Inst. of Washington for 1916, pp. 79 and 80.

A mixture of agar 90 parts and glycocoll 10 parts gave the following swelling coefficients:

DISTILLED WATER	HUNDREDTH NORMAL HYDROCHLORIC ACID	HUNDREDTH NORMAL SODIUM HYDRATE
per cent	*per cent*	*per cent*
2800	1000	500

A cell which reacted as did these plates of "plant-colloid" would be notably affected by acidity or alkalinity, especially in the imbibition of water from protoplasts with which it might be in contact.

Acidity and alkalinity are conditions encountered very nearly all the time in the cell, but these are not the only factors affecting imbibition. Salts, especially of potassium and calcium, are practically always in solution in cell sap. It is customary to say that some salts increase the swelling power of gels, but most of such assertions rest upon the results of experiments with gelatine.

Mixtures of agar and any protein substance swell less in any salt solution than in distilled water. The swelling of a mixture of 90 parts agar and 10 parts glycocoll in salts is illustrated by the figures in table 1.

When plant-colloids are affected in this differential manner by acids, alkalies and salts, it is obvious without further citation of experimental results that these and other features may play a part in the possibilities of parasitism. Combinations are

TABLE 1

Swelling of mixtures of protein and agar

WATER	HUNDREDTH MOLECULAR	FIFTIETH MOLECULAR	TENTH MOLECULAR
Potassium nitrate			
per cent	*per cent*	*per cent*	*per cent*
3266	1800	1733	1333
Calcium nitrate			
	1333	1200	800

possible which may cause water absorption in great volume independently of osmosis and in fact in opposition to it.[3]

The penetration of a host by the haustorium of a parasite is not to be regarded as conditioned by the simple osmotic balance between two tracts of cells of equivalent physical condition. The invaded tracts of the host are usually composed of expanded vacuolated cells in which osmosis resulting from the solutions in the vacuoles is the dominant hydrostatic agent, although the colloids suspended in these vacuoles, and the denser colloids of the cytoplasm have their own imbibitional capacities.

The younger cells of the haustorium which push into such masses are probably not yet vacuolated. Absorption by them is almost wholly by imbibition and this would be carried on against any probable osmotic action of a vacuolated cell. Thus a thin plate of "plant colloid" mixture absorbed water from a solution of potassium nitrate which had an osmotic coefficient of 60 atmospheres, and swelled about 400% in volume in fifteen hours.

A second feature, the force of expansion of the invading protoplasts, would be no less important. The pressure set up, like that of a swelling seed, would be great enough to cause mechanical penetration of the host, as it would be far greater than any force attributable to osmotic action.

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[3] See MacDougal, D. T. Imbibitional Swelling of Plants and Colloidal Mixtures. Science, N. S., **44**: 502–505, October 6, 1916.

Also, MacDougal, D. T. and Spoehr, H. A. The Behavior of Certain Gels Useful in the Interpretation of the Action of Plants. Science, N. S. **45**: 484–488, 1916.

After the haustorial development has carried that organ to a mature stage the nutritive contact with the host is one in which osmosis doubtless plays an important part. The proportion of nitrogenous substance in the parasite, the acidity, and the concentration of salts might be the determining factors in both the making and maintenance of a nutritive couple of host and parasite.

AN ENUMERATION OF THE PTERIDOPHYTES AND SPERMATOPHYTES OF THE SAN BERNARDINO MOUNTAINS, CALIFORNIA

S. B. PARISH

San Bernardino, California

CACTACEAE

Cereus (*Echinocereus*) *mohavensis* E. & B. Pac. R. Rep. **4**: 33 t. 4, f. 8.

In dense caespitose masses on rocky or stone steeps in cañons of the Piñon Zone. Cushenberry Cañon. Green Lead. In smaller clusters on ridges in Bear Valley.

Opuntia Covillei Britton & Rose, Smiths. Misc. Coll. 50, pt. **4**: 332. (?)

On the rocky shores of Baldwin Lake, Bear Valley. Mill Creek Cañon near Forest Home. Seven Oaks. All these stations are in the Upper Transition Zone, but the species is of the arid mesas of San Bernardino Valley, and the reference is unsatisfactory.

ONAGRACEAE

Zauschneria californica Presl. Rel. Haenk. **2**: 28, t. 52.

Frequent on dry or stony banks in the Upper Chaparral and Lower Transition Zones.

Chamaenerion angustifolium Scop. Fl. Car. ed. 2, **1**: 271.

Occasional along streams in the Upper Transition and Canadian Zones.

Epilobium adenocaulon Hausskn. Oesterr. Bot. Zeit. **29**: 119.

In meadows in the Transition Zone.

Epilobium anagallidifolium Lam. Dict. **2**: 376.

In a meadow, Bluff Lake.

Epilobium glaberrimum Barbey, in Brew. & Wats. Bot. Cal. **1**: 220.

Frequent in moderately dry soil in the Transition Zone.

Epilobium paniculatum Nutt.; T. & G. Fl. **1**: 490.

Frequent in the Transition Zone.

Epilobium ursinum Parish; Trel. Rept. Mo. Bot. Gard. **2**: 100.

Frequent in wet meadows in the Transition Zone.

Gayophytum pumilum Wats. Proc. Am. Acad. **18**: 193.

Occasional in dry meadows in the Lower Transition Zone.

Gayophytum ramosissimum T. & G. Fl. **1**: 513.

Frequent on flats in the Lower Transition Zone.

Oenothera (*Sphaerostigma*) *bistorta* Nutt.; T. & G. Fl. **1**: 508.

Frequent in cañons in the Chaparral Zone.

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Oenothera bistorta Nutt. var. *Reedii* Parish, comb. mov. *Sphaerostigma bistorta* Walp. var. *Reedii* Parish, Muhl. **3**: 107.
Occasional on dry hills in the Chaparral Zone.

Oenothera (*Pachylophusa*) *caespitosa* Nutt.; Fras. Cat.
Rare, Cushenberry Cañon in the Piñon Zone.

Oenothera (*Anogra*) *californica* Wats. in Brew. & Wats. Bot Cal. **1**: 223.
Occasional on hillsides in Bear Valley.

Oenothera (*Onagra*) *Hookeri* T. & G. Fl. **1**: 493.
Occasional in meadows and by streams in the Transition Zone.

Oenothera (*Eulobus*) *leptocarpa* Greene, Pitt. **1**: 302.
Frequent in dry soil in the Lower Chaparral Zone.

Oenothera (*Sphaerostigma*) *strigulosa* T. & G. Fl. **1**: 512.
Frequent in dry soil in the Lower Chaparral Zone.

Godetia Bottae Spach, Monog. Onagr. 73.
Abundant in cañons in the Lower Chaparral Zone.

Godetia quadrivulnera Spach, Monog. Onagr. 69.
Frequent in cañons in the Lower Chaparral Zone.

Clarkia rhomboidea Dougl.; Hook. Fl. Bor. Am. **1**: 214.
Frequent in moist soil in the Upper Chaparral and Lower Transition Zones.

Clarkia xantiana Gray, Proc. Bost. Soc. Nat. Hist. **7**: 145.
Rare. Bluff Lake, *Miss Huchinson.*

Boisduvalia Douglasii Spach, Monog. Onagr. 80, t. 31, f. 2.
Occasional in meadows in the Lower Transition Zone.

Heterogaura californica Rothr. Proc. Am. Acad. **6**: 354.
Frequent on shady banks in the Lower Transition Zone.

Circaea pacifica Aschers. & Mag. Bot. Zeit. **29**: 392.
Occasional in damp thickets in the Lower Transition Zone.

HALORRHAGIDACEAE

Hippurus vulgaris Linn. Sp. Pl. 4.
In shallow water, Bear Valley.

Myriophyllum spicatum Linn. Sp. Pl. 992.
Abundant in Bear Valley Reservoir.

ARALIACEAE

Aralia californica Wats. Proc. Am. Acad. **11**: 114.
On the borders of streams in shady places in the Upper Transition Zone.

UMBELLIFERAE

Hydrocotyle umbellata Linn. Sp. Pl. **1**: 234.
Seven Oaks, *Grant.* A common species in San Bernardino Valley.

Sanicula nevadensis Wats. Proc. Am. Acad. **11**: 139.
Occasional on open pine ridges in the Lower Transition Zone.

Sanicula Menziesii H. & A. Bot. Beechey 142.
Frequent on shady banks in the cañons of the Lower Chaparral Zone.

Osmorhiza brachypoda Torr. Jour. Philad. Acad. n. sér. **3**: 89.
Frequent on shady banks of the cañons of the Lower Chaparral Zone.
Osmorrhiza nuda Torr. Pac. R. Rept. 4, 93.
Occasional on shady banks in cañons of the Lower Chaparral Zone.
Deweya arguta T. & G. Fl. **1**: 641.
Frequent on rocky hillsides in the Chaparral Zone.
Drudeophytum Parishii C. & R. Contr. Nat. Herb. **7**: 82.
Frequent on rocky hillsides in Cushenberry Cañon, in the Piñon Zone, and occasional in the Lower Transition Zone.
Drudeophytum vestitum C. & R. Contr. Nat. Herb. **7**: 83.
Infrequent on stony hills, Bear Valley. To be expected at higher altitudes.
Eulophus Parishii C. & R. Rev. Umbell. 112.
Abundant on pine flats and in dry meadows in Bear Valley, and occasional elsewhere in the Upper Transition Zone.
Sphaenosciadium eryngiifolium C. & R. Contr. Nat. Herb. **7**: 128.
Occasional by stream banks in the Upper Transition Zone.
Angelica tomentosa Wats. Proc. Am. Acad. **11**: 141.
Frequent on stream banks in the Upper Chaparral and Transition Zones.
Leptotenia multifida Nutt.; T. & G. Fl. **1**: 630.
Infrequent on dry hills in the Chaparral Zone.
Cogswellia Parishii C. & R. Contr. Nat. Herb. **12**: 450.
Frequent on stony hillsides in Bear Valley.
Euryptera lucida Nutt.; T. & G. Fl. **1**: 629.
Rather rare in dry soil in the Lower Chaparral Zone.
Heracleum lanatum Linn. Sp. Pl. 249.
Frequent on stream banks in the Upper Chaparral and Transition Zones.

CORNACEAE

Cornus californica C. A. Mey. Bull. Phys.-Math. Acad. Petersb. **3**: 372.
Frequent along stream banks in the Lower Transition Zone.
Cornus Nuttallii Audubon; T. & G. Fl. **1**: 625. Dogwood.
Frequent near streams in the Lower Transition Zone.
Garrya pallida Eastw. Bot. Gaz. **36**: 460.
Mill Creek cañon, in the Upper Transition Zone.
Garrya Veatchii Kellogg. var. *Palmeri* Eastw. Bot. Gaz. **36**: 458.
Occasional on dry hills and in washes in the Lower Chaparral and Lower Piñon Zones.

MONOTROPACEAE

Pterospora andromedea Nutt. Gen. **1**: 269.
Frequent in pine forest in the Transition and Canadian Zones.
Sarcodes sanguinea Torr. Pl. Frem. 17, t. 10. Snow Plant.
Frequent in open pine forest in the Transition and Canadian Zones.

PYROLACEAE

Chimaphila Menziesii Spreng. Syst. **2**: 317.
Rare in the Upper Transition Zone. Mill Creek Falls and Snow Cañon.

Pyrola aphylla Smith; Hook. Fl. Bor. Am. **2**: 48, t. 137.
Occasional in pine forest in the Transition Zone.
Pyrola picta Smith var. *pallida* Parish, comb. nov. *P. pallida* Greene, Pitt. **4**: 39.
Whitewater Basin, Upper Transition Zone, *Mrs. Wilder.*

ERICACEAE

Bryanthus Breweri Gray, Proc. Am. Acad. **7**: 367.
San Gorgonio Mountain, in the Canadian Zone, *Wright.*
Arctostaphylos glauca Lindl. Bot. Reg. 21, t. 179.
Frequent on dry hillsides in the Upper Chaparral and Lower Transition Zones.
Arctostaphylos patula Greene, Pitt. **2**: 171.
Frequent on hillsides in the Upper Transition Zone.
Arctostaphylos Pringlei var. *drupacea* Parry, Bull. Cal. Acad. **2**: 494.
Occasional in cañons of the Transition Zone.
Arctostaphylos pungens HBK. Nov. Gen. & Sp. **3**: 278, t. 259.
Occasional on hillsides in the Upper Transition Zone.
Arctostaphylos tomentosa Dougl. Bot. Reg. 21, t. 7911.
Occasional on hillsides in the Upper Chaparral and Lower Transition Zones.

PRIMULACEAE

Dodecatheon alpinum Greene, Eryth. **3**: 39.
Frequent on stream banks at Bluff Lake.
Androsace septentrionalis Linn. var. *subulifera* Gray, Synop. Fl. 2, pt. **1**: 69.
San Gorgonio Mountains, *Hall 7642*, in hb. Univ. Cal.

STYRACACEAE

Styrax californica Torr. Smith. Contr. **6**: 4.
Abundant on cañon sides in the Chaparral Zone.

OLEACEAE

Fraxinus dipetala H. & A. Bot. Beech. 362, t. 87.
Mill Creek Cañon, in the Lower Chaparral Zone.
Fraxinus coriacea Wats. Am. Natur. **7**: 30.
Cleghorn Cañon, acc. Abrams in Bull. N. Y. Bot. Gard. **6**: 436.

GENTIANACEAE

Gentiana acuta Michx. Fl. **1**: 177.
Occasional on damp banks in the Upper Transition and Canadian Zones.
Gentiana detonsa Rottb. Act. Hafn. **10**: 254, t. 1.
Locally abundant in wet meadows near Knight's Camp, Bear Valley.
Gentiana humilis Stev. Act. Mosq. **3**: 258. *G. viridula* Parish, Bot. Gaz. **38**: 461.
On the borders of a stream, South Fork of Santa Ana River, in the Canadian Zone, *Mrs. Wilder.*

Gentiana simplex Gray, Proc. Am. Acad. **6**: 87, t. 16.

Occasional in meadows in the Transition and Canadian Zones.

Frasera neglecta Hall, Bot. Gaz. **31**: 388.

Frequent on open forested flats and hillsides in Upper Holcomb Valley.

APOCYNACEAE

Amsonia brevifolia Gray, Proc. Am. Acad. **12**: 64.

In dry soil at Cactus Flat in the Piñon Zone.

Amsonia tomentosa Torr. Frem. 2d Rept. 316.

Growing with the foregoing species.

Apocynum androsaemifolium Linn. Sp. Pl. 213.

Frequent in rocky places in the Transition Zone.

ASCLEPIADACEAE

Asclepias eriocarpa Benth. Pl. Hartw. 323.

Occasional in dry soil in the Lower Transition Zone.

Asclepias mexicana Cav. Ic. **1**: 42, t. 58.

Infrequent in damp soil in the Lower Chaparral Zone.

CONVOLVULACEAE

Convolvulus occidentalis Gray, Proc. Am. Acad. **11**: 89.

Occasional among bushes in the Lower Chaparral Zone.

Convolvulus luteolus var. *fulcratus* Gray, Proc. Am. Acad. **11**: 90.

Occasional on dry open slopes in the Lower Transition Zone.

Cuscuta californica Choisy, Cusc. 183.

Very abundant, infesting shrubs, on dry hills in the Lower Chaparral Zone.

POLEMONIACEAE

Polemonium coeruleum Linn. Sp. Pl. 162.

Bear Valley, *Hall* and Upper Meadows on the South Fork of Santa Ana River, *Mrs. Wilder*, in each instance only a single plant.

Collomia grandiflora Dougl.; Lindl. Bot. Reg. 14, t. 1166.

Frequent in open pine forest in the Transition Zone.

Collomia heterophylla Hook. Bot. Mag. 56, t. 2895.

Frequent on dry slopes in the Lower Chaparral Zone.

Collomia linearis Nutt. Gen. **1**: 126.

In meadows, Bear Valley.

Phlox austromontana Coville, Contr. Nat. Herb. **4**: 151.

In dense mats, in dry soil, at the upper end of Bear Valley.

Phlox dolichantha Gray, Proc. Am. Acad. **22**: 310.

Common in open pine forest in Bear Valley.

Gilia achilleifolia Benth. Bot. Reg. **19**: t. 1622.

Common on sheltered banks in cañons of the Lower Chaparral Zone.

Gilia californica Benth.; DC. Prodr. **9**: 316.

Abundant on dry banks in the Lower Chaparral Zone.

Gilia ciliata Benth. Pl. Hartw. 325.

Common on dry banks in the Lower Chaparral Zone.

Gilia dichotoma Benth. DC. Prodr. **9**: 314.

A desert species found scantily in the cañon of City Creek in the Lower Chaparral Zone.

Gilia latiflora Gray, Synop. Fl. 2, pt. 1: 147.

Rare, Mill Creek, in the Lower Chaparral Zone.

Gilia leptantha Parish, Zoe **5**: 74.

Seven Oaks, Transition Zone (type), *Grout*.

Gilia liniflora Benth. var. *pharnacioides* Gray, Proc. Am. Acad. **8**: 363.

Frequent in dry soil in the Lower Chaparral Zone.

Gilia montana Parish, comb. nov. *Linanthus montanus* Greene, Eryth. **3**: 120.

Frequent on dry slopes in the Transition Zone.

Gilia Nuttallii Gray, Proc. Am. Acad. **8**: 267.

In rocky soil on the mountain side above Seven Oaks.

Gilia pungens Benth. var. *Hookeri* Gray, Proc. Am. Acad. **8**: 268.

Occasional in rocky places in the Upper Transition and Canadian Zones.

Gilia pungens Benth. var. *tenuiloba* Millik. Univ. Cal. Publ. Bot. **2**: 41.

Occasional in rocky places in the Upper Transition and Canadian Zones.

Gilia subalpina Brand, Pflanzenr. IV, **250**: 98.

Green Valley, in the Lower Transition Zone, acc. Brand, *l. c.*

Gilia tenuiflora Benth. var. *altissima* Parish, Eryth. **6**: 90.

Abundant on dry ridges in the Lower Transition Zone, the type region.

Navarretia Breweri Greene, Pitt. 1: 137.

On dry slopes in Bear Valley; the southern limit of the species.

Navarretia densifolia Brand, Pflanzenr. IV, 250: 165.

Frequent in coarse dry soil in the Upper Transition Zone.

Navarretia virgata Brand, Pflanzer. IV, **250**: 167.

Abundant in dry soil in the Lower Chaparral Zone.

HYDROPHYLLACEAE

Ellisia chrysanthemifolia Benth. Trans. Linn. Soc. **17**: 274.

Occasional in damp shady places in the Lower Chaparral Zone.

Memophila Menziesii H. & A. var. *integrifolia* Parish, Eryth. **6**: 91.

Frequent, mostly in shady places, in the Chaparral and Lower Transition Zones. The type was from the head of Waterman Cañon.

Nemophila sepulta Parish, Eryth. **7**: 93.

Abundant on rich banks and in meadows in Bear Valley (the type station) and occasional elsewhere in the Upper Transition Zone.

Phacelia brachyloba Gray, Proc. Am. Acad. **10**: 324.

Occasional, often abundant in burned places, in the cañons of the Lower Chaparral Zone.

Phacelia curvipes Torr. & Wats. var. *pratensis* Brand, Univ. Cal. Publ. Bot. **4**: 222.

Abundant in open pine forest in Bear Valley, and occasional elsewhere in the Transition Zone.

Phacelia curvipes Torr. & Wats. var. *grandiflora* Brand, Pflanzenr. IV, **251**: 116.

Occasional in dry soil in the Upper Chaparral and Lower Transition Zones.

Phacelia distans Benth. Bot. Sulph. 36.

Frequent on open hillsides in the Lower Chaparral Zone.

Phacelia hispida Gray, Syn. Fl. 2, pt. **1**: 161.

Frequent on shady hillsides in the Lower Chaparral Zone.

Phacelia magellanica Coville f. *alpina* Brand, Univ. Cal. Publ. Bot. **4**: 217.

Frequent on dry gravelly hillsides in the Upper Transition Zone.

Phacelia magellanica Coville f. *egina* Brand, Pflanzenr. IV, **251**: 218.

Green Valley, in the Lower Transition Zone, *Hall 1317*.

Phacelia magellanica Coville f. *virgata* Brand, Univ. Cal. Publ. **4**: 219.

Frequent in dry soil in cañons of the Upper Chaparral Zone.

Phacelia mohavensis var. *exilis* Gray, Synop. Fl. 2, pt. 1: 165.

Frequent in open pine forest in the Transition Zone. Bear Valley is the type station.

Phacelia ramosissima Dougl. var. *suffrutescens* Parry; Gray, Synop. Fl. 2, pt. 1: 416.

Frequent on bushy banks in the cañons of the Lower Chaparral Zone.

Phacelia Whitlavia Gray, Proc. Am. Acad. **10**: 322.

Occasional on open banks in the Lower Chaparral Zone.

Emmenanthe penduliflora Benth. Trans. Linn. Soc. **17**: 281.

Occasional on banks in the Lower Chaparral Zone.

Nama Parryi Gray in Brew. & Wats. Bot. Cal. **1**: 621.

Occasional in dry soil in the Chaparral, Lower Transition and Piñon Zones.

Nama Rothrockii Gray in Brew. & Wats. Bot. Cal. **1**: 621.

Locally abundant on a dry ridge between Holcomb Valley and Green Lead.

Hesperochiron californicum Wats. King's Expl. **5**: 280, t. 30.

Abundant in some damp meadows in Bear Valley, as at the mouth of Grout Creek.

Eriodictyon trichocalyx Heller, Muhl. **1**: 108.

Seven Oaks, *Grant*, type.

BORAGINACEAE

Lappula floribunda Greene, Pitt. **2**: 182.

Frequent in open pine forest and dry meadows in the Upper Piñon, Upper Transition and Canadian Zones.

Allocarya hispidula Greene, Pitt. **1**: 17.

In meadows at Bear Valley.

Oreocarya confertiflora Greene, Pitt. **3**: 112.

Occasional on dry hillsides in the Piñon Zone. Cushenberry Cañon and Rose Mine.

Oreocarya suffruticosa Greene var. *abortiva* Macbr. Proc. Am. Acad. **51**: 547.

Frequent in dry meadows in Bear Valley, the type station.

Eremocarya micrantha Greene var. *lepida* Macbr. Proc. Am. Acad. **51**: 345.

Frequent in dry sandy soil in the Transition Zone.

Plagiobothrys asper Greene, Pitt. **3**: 262.

Little Bear Valley in the Lower Transition Zone.

Plagiobothrys ursinus Gray, Proc. Am. Acad. **20**: 285.

Frequent in dry meadows in Bear Valley, the type station.

Cryptanthe horridula Greene, Pitt. **5**: 55.
"Summit of the dividing ridge between San Bernardino Valley and the Mojave Desert," acc. Greene, *l. c.*

Cryptanthe microstachys Greene, Pitt. **1**: 116.
Frequent in dry soil in the cañons of the Lower Chaparral Zone.

VERBENACEAE

Verbena prostrata R. Br. Hort. Kew. ed. 2, **4**: 41.
Occasional in damp soil in the Chaparral Zone.

LABIATAE

Trichostema micranthum Gray, Synop. Fl. 2, pt. 1: 348.
Frequent in dry soil in the Transition Zone, the type region.

Trichostema Parishii Vasey, Bot. Gaz. **5**: 173.
Occasional on dry hills in the Lower Chaparral Zone.

Mentha arvensis Linn. var. *glabrata* Fernald in Gray's Man. ed. 7, 711.
Frequent in meadows and near streams in the Transition Zone.

Mentha rotundifolia Huds. Fl. Angl. 221.
Locally established along Waterman Creek, near Vail's.

Pycnanthemum californicum Torr. Journ. Acad. Philad. n. s. **2**: 99.
Occasional in damp soil in cañons of the Chaparral Zone.

Scutellaria angustifolia Pursh, Fl. **2**: 412.
Frequent in stony soil and rock crevices in the Transition Zone.

Monardella australis Abrams, Muhl, **8**: 34.
Frequent in dry soil throughout the Transition Zone.

Monardella lanceolata Gray, Proc. Am. Acad. **11**: 102.
Frequent in dry soil in the Chaparral Zone.

Monardella linoides Gray. var. *stricta* Parish, Eryth. **7**: 96.
Frequent on dry hillsides in the Upper Transition and Canadian Zones.

Monardella macrantha Gray var. *Hallii* Abrams, Muhl. **8**: 29.
Locally abundant in Mill Creek cañon near the quarry, in the Lower Chaparral Zone.

Salvia apiana Jeps. Muhl. **3**: 144. White Sage.
Abundant on dry hillsides and benches in the Lower Chaparral Zone.

Salvia mellifera Greene, Bull. Cal. Acad. 1: 236. Black Sage.
Abundant on dry hillsides and benches in the Lower Chaparral Zone.

Salvia pachystachya Parish, Eryth. **6**: 191.
Occasional on dry slopes in the Upper Transition Zone. Bear Valley is the type station.

Salvia pilosa Merriam, N. A. Fauna **7**: 322.
Frequent on dry hillsides in the Lower Piñon Zone, the type region.

Agastache urticifolia Kuntze, Rev. Pl. 511.
Locally abundant along streams at Oak Glen and Potato Cañon in the Lower Chaparral Zone.

Prunella vulgaris Linn. var. *lanceolata* Fernald, Rhod. **15**: 183.
Occasional in wet meadows in the Transition Zone.

Stachys adjugoides Benth. Linnaea **6**: 80.
Occasional in wet soil in the Transition Zone.
Stachys albens Gray, Proc. Am. Acad. **7**: 387.
Frequent in damp soil in Bear Valley.

SOLANACEAE

Nicotiana attenuata Torr. ;Wats. King's Expl. **5**: 276.
Occasional on dry slopes in the Transition Zone.
Solanum Xanti Gray, Proc. Am. Acad. **11**: 90.
Occasional in open ground in the Chaparral and Transition Zones.
Solanum Xanti Gray var. *intermedium* Parish, Proc. Cal. Acad. ser. 3, **2**: 168.
Frequent on dry bushy or rocky banks in the Lower Chaparral Zone.

SCROPHULARIACEAE

Scrophularia californica Cham. Linnaea **2**: 585.
Occasional in cañons in the Lower Chaparral Zone.
Collinsia bartsiaefolia Benth. in DC. Prodr. **10**: 318.
Frequent in cañons in the Upper Chaparral Zone.
Collinsia Childii Parry; Gray in Brew. & Wats. Bot. Cal. **1**: 237.
Frequent on damp banks in the Transition Zone; the type region.
Collinsia grandiflora Dougl. var. *pusilla* Gray, Syn. Fl. 2, pt. 1: 256.
Abundant in wet sand in Bear Valley.
Collinsia Parryi Gray, Syn. Fl. 2, pt. 1: 257.
Frequent on damp banks in cañons of the Lower Chaparral Zone; the type region.
Pentstemon Bridgesii Gray, Proc. Am. Acad. **7**: 379.
Occasional on hillsides in the Upper Transition Zone.
Pentstemon caesius Gray, Proc. Am. Acad. **19**: 92.
Frequent among rocks above Bear Valley, the type station.
Pentstemon cordifolius Benth. in DC. Prodr. **10**: 329.
Frequent among shrubs in cañons of the Chaparral Zone.
Pentstemon Eatoni Gray, Proc. Am. Acad. **8**: 395.
Occasional in cañons in the Lower Piñon Zone.
Pentstemon heterophyllus Lindl. Bot. Reg. t. 1899.
Occasional on hillsides in the Lower Chaparral Zone. Mill Creek.
Pentstemon labrosus Hook. f. Bot. Mag. t. 6738.
Abundant in open pine forest in the Lower Transition Zone.
Pentstemon Palmeri Gray, Proc. Am. Acad. **7**: 378.
Common on dry open ridges in the Transition Zone.
Pentstemon ternatus Torr. Bot. Mex. Bound. 115.
Frequent among shrubs in the cañons of the Lower Chaparral Zone.
Mimulus cardinalis Dougl.; Lindl. Hort. Trans. **2**: 70, t. 3.
Frequent on stony stream banks in the Lower Chaparral Zone.
Mimulus floribundus Dougl.; Lindl. Bot. Reg. t. 1125.
Occasional in damp shady places in the Lower Chaparral Zone.
Mimulus (*Diplacus*) *glutinosus* Wendl. var. *brachypus* Gray in Brew. & Wats. Bot. Cal. **1**: 563.
Abundant on cañon sides in the Chaparral Zone.

Mimulus Langsdorfii Don; Sims Bot. Mag. t. 51.

Abundant along streams and in wet places in the Chaparral and Transition Zones.

Mimulus Langsdorfii Don var. *nasutus* Jeps. Fl. W. Mid. Cal. 407.

Occasional in damp shady places, especially among rocks, in the Chaparral Zone.

Mimulus Langsdorfii Don var. *Tilingii* Greene, Lond. Journ. Bot. **33**: 8.

Borders of cold springs and streams in the Upper Transition and Canadian Zones.

Mimulus moschatus Dougl. var. *sessilifolius* Gray, Syn. Fl. 2, pt. 1: 447.

Frequent on wet banks in the Transition Zone.

Mimulus Palmeri Gray, Proc. Am. Acad. **12**: 82.

Abundant on flats in the Transition Zone.

Mimulus exiguus Gray, Proc. Am. Acad. **20**: 307.

On damp sandy flats. Bear Valley. Bluff Lake.

Mimulus primuloides Benth. Scroph. Ind. 28.

Abundant in wet meadows. Bear Valley. Bluff Lake.

Mimulus rubellus Gray; Torr. Bot. Mex. Bound. 116.

Rare in moist soil in the Transition Zone.

Limosella aquatica Linn. Sp. Pl. 631.

Rare on the muddy banks of shallow ponds. Bear Valley. Bluff Lake.

Veronica americana Schwein.; Benth. in DC. Prodr. **10**: 468.

Abundant in shallow water and along stream banks in Bear Valley.

Veronica serpyllifolia Linn. Sp. Pl. 12.

In swampy places at Bear Valley and Bluff Lake.

Castilleja cinerea Gray, Proc. Am. Acad. **19**: 95.

Abundant on stony hillsides at the upper end of Bear Valley, the type station.

Castilleja foliolosa H. & A. Bot. Beechey 154.

Frequent on dry bushy hillsides in the Lower Chaparral Zone.

Castilleja linearifolia Benth. in DC. Prodr. **10**: 468.

Frequent on hillsides in Bear Valley.

Castilleja Martini Abrams, Bull. S. Cal. Acad. **1**: 69.

Frequent on hillsides in the Upper Chaparral and Lower Transition Zones, and occasional in the Piñon Zone.

Castilleja stenantha Gray, Syn. Fl. 2, pt. 1: 295.

Occasional in wet meadows in the Chaparral and Transition Zones.

Orthocarpus lasiorhynchus Gray, Proc. Am. Acad. **12**: 82.

Abundant on damp flats in the Transition Zone.

Cordylanthus Nevinii Gray, Proc. Am. Acad. **17**: 229.

Frequent in open pine forest in the Transition Zone, the type region.

Pedicularis semibarbata Gray, Proc. Am. Acad. **7**: 385.

Abundant in open pine forest in the Transition Zone.

OROBANCHACEAE

Aphyllon comosum Gray in Brew. & Wats. Bot. Cal. **1**: 584.

Rare. Bear Valley.

Boschniakia strobilacea Gray, Pac. R. Rept. **4**: 118.
Very rare. San Gorgonio Mountain, in the Hudsonian Zone, *Wright*.

LENTIBULARIACEAE

Utricularia vulgaris Linn. Sp. Pl. 18.
Abundant, floating in ponds, and now in the reservoir, in Bear Valley.

RUBIACEAE

Kelloggia galioides Torr. Wilkes Exped. **17**: 332, t. 6.
Very common in dry rocky places in the Transition Zone.
Galium Andrewsii Gray, Proc. Am. Acad. **6**: 288.
Occasional in dry shady places in the Upper Chaparral Zone.
Galium aparine Linn. Sp. Pl. 108.
Occasional in damp shady places in the Lower Chaparral Zone.
Galium bifolium Wats. King's Expl. **5**: 134, t. 14.
Rare. Bear Valley, *Davidson*.
Galium Brandegii Gray, Proc. Am. Acad. **12**: 58.
Occasional in meadows, Bear Valley and Bluff Lake.
Galium multiflorum Kellogg, Proc. Cal. Acad. **2**: 97, t. 26.
Frequent on dry stony hills about Bear Valley.
Galium multiflorum Kellogg var. *parvifolium* Parish, Zoe **5**: 54.
Frequent on dry stony hills in the Upper Transition and Canadian Zones.
Galium trifidum Linn. var. *subbiflorum* Wiegand, Bull. Torr. Club **24**: 399.
In wet meadows, Bear Valley; type station.
Galium triflorum Michx. Fl. Bor. Am. **1**: 80.
Frequent along shady stream banks in the Lower Chaparral Zone.

CAPRIFOLIACEAE

Sambucus velutinus Dur. & Hilg. Pac. R. Rept. **5**: 8.
Bear Valley, *Hall 1847*, in hb. Univ. Cal.
Symphoricarpus Parishii Rydb. Bull. Torr. Club **26**: 545.
Abundant on dry hills in the Upper Transition and Canadian Zones, type region.
Symphoricarpus mollis Nutt.; T. & G. Fl. **2**: 13.
Frequent in cañons of the Chaparral Zone.
Lonicera interrupta Benth. Pl. Hartw. 313.
Rare. Waterman Cañon in the Upper Chaparral Zone.
Lonicera subspicata H. & A. Bot. Beech. 349.
Frequent among shrubs in the Chaparral Zone.

CAMPANULACEAE

Specularia biflora Gray, Proc. Am. Acad. **11**: 82.
Rare in the Transition Zone. Fawnskin Park.
Heterocodon rariflorum Nutt. Trans. Am. Phil. Soc. n. ser. **8**: 255.
Rare in the Transition Zone. Lapraix Mill.

LOBELIACEAE

Lobelia splendens Willd. Hort. Berol. t. 86.
Occasional in wet meadows in the Transition Zone.

COMPOSITAE

Microseris linearifolia Schultz Bip. Pollichia **12–24**: 308.
Occasional on damp banks in the Lower Chaparral Zone.
Stephanomeria cichoriacea Gray, Proc. Am. Acad. **7**: 552.
Abundant on rocky banks in the Upper Chaparral Zone.
Stephanomeria virgata Benth. Bot. Sulph. 32.
Frequent on dry banks in the Lower Chaparral Zone.
Rafinesquia californica Nutt. Trans. Am. Philos. Soc. ser. 2, **7**: 429.
Occasional among bushes in the Lower Transition Zone.
Malacothrix saxatilis T. & G. Fl. **2**: 486.
Rare on rocky banks, Mill Creek, in the Lower Chaparral Zone.
Taraxicum officinale Weber var. *lividum* Koch, Fl. Germ. 428.
Abundant in wet meadows in the Transition and Canadian Zones.
Troximon heterophyllum Greene f. *normale* Hall, Univ. Cal. Publ. Bot. **3**: 277.
Frequent in dry meadows in the Transition Zone.
Troximon retrorsum Gray, Proc. Am. Acad. **9**: 216.
Frequent in open pine forest in the Transition, and occasional in cañons in the Upper Chaparral Zone.
Troximon plebeium Greene, Pitt. **2**: 79.
Occasional in the Lower Transition Zone.
Crepis acuminata Nutt. Trans. Am. Philos. Soc. ser. 2, **7**: 437.
Frequent on dry slopes in the Upper Transition Zone.
Crepis occidentalis Nutt. Jour. Acad. Philad. **7**: 29.
Frequent on dry slopes in the Upper Transition Zone.
Crepis occidentalis Nutt. var. *subacaulis* Kellogg, Proc. Cal. Acad. **5**: 50.
Bear Valley, acc. Coville, Contr. Nat. Herb. **3**: 562.
Hieracium albiflorum Hook. Fl. Bor. Am. **1**: 298.
Frequent in crevices of rocks in the Upper Transition Zone.
Hieracium Grinnellii Eastw. Bull. Torr. Club **32**: 217.
Fish Creek, in the Upper Transition Zone, acc. Hall, Univ. Cal. Publ. Bot. **3**: 285.
Hieracium horridum Fries, Epic. Hier. 154.
Frequent in rocky places in the Upper Transition and Canadian Zones.
Hieracium Parishii Gray, Proc. Am. Acad. **19**: 67.
Along a rocky ledge above Vail's in Waterman cañon, in the Lower Transition Zone; type station.
Brickellia arguta Robins. Mem. Gray Hb. **1**: 102, t. 79.
Occasional in rocky places in the Lower Piñon Zone.
Brickellia oblongifolio Nutt. var. *linifolia* Robins. Mem. Gray Herb. **1**: 104.
Locally abundant on dry stony flats above Cactus Flat and at Rose Mine, both in the Upper Piñon Zone.
Gutierrezia californica T. & G. Fl. **2**: 195.
Bear Valley, in the Upper Transition Zone.

Chrysopsis Wrightii Gray, Synop. Fl. 1. pt. **2**: 446.

Near the summit of San Gorgonio Mountain, *W. G. Wright*, July, 1882, acc. Gray, *l. c.*, but not since met with.

Solidago californica Nutt. Trans. Am. Philos. Soc. ser. 2, **7**: 328.

Frequent on dry slopes in the Upper Chaparral and Transition Zones.

Solidago confinis Gray var. *luxurians* Hall, Univ. Cal. Publ. Bot. **3**: 46.

Locally abundant in wet mucky soil at Arrowhead Hot Springs in the Lower Chaparral Zone.

Aplopappus gossypinus Hall, Univ. Cal. Publ. Bot. **3**: 49.

Frequent in meadows in Bear Valley (type) and Holcomb Valley.

Ericameria cuneata McClatchie var. *spathulata* Hall, Univ. Cal. Publ. Bot. **3**: 52.

Frequent in rock crevices in the Lower Piñon Zone.

Ericameria Parishii Hall, Univ. Cal. Publ. Bot. **3**: 55.

Occasional on dry hillsides in the Lower Chaparral Zone. Waterman Cañon is the type station.

Chrysothamnus nauseosus Britton, in Britt. & Brown Ill. Fl. **3**: 326.

Occasional in dry soil in the Lower Transition Zone.

Chrysothamnus nauseosus Britton var. *occidentalis* Piper, Contr. Nat. Herb. **11**: 59.

Frequent in dry soil in the Lower Transition Zone.

Chrysothamnus viscidiflorus Nutt. var. *stenophyllus* Hall. Univ. Cal. Publ. Bot. **3**: 58.

Occasional on dry ridges in Bear and Holcomb Valleys.

Hazardia squarrosa Greene, Eryth. **2**: 112.

Frequent on dry banks in the Lower Chaparral Zone.

Corethrogyne filaginifolia Nutt. var. *bernardina* Hall. Univ. Cal. Publ. Bot. **3**: 71.

Frequent in dry soil in the Lower Chaparral Zone.

Corethrogyne filaginifolia Nutt. var. *glomerata* Hall. Univ. Cal. Publ. Bot. **3**: 72.

Oak Glen, in the Lower Transition Zone, *Geo. Robertson*, type.

Corethrogyne filaginifolia Nutt. var. *rigida* Gray, Syn. Fl. 1 pt. **2**: 170.

Frequent on stony hillsides in cañons in the Upper Chaparral Zone.

Aster canescens Pursh, Fl. **2**: 547.

Infrequent in the Upper Transition Zone.

Aster delectabilis Hall, Univ. Cal. Publ. Bot. **3**: 82.

Frequent in wet meadows in the Upper Transition and Canadian Zones. The type was collected by *R. J. Smith* on a tributary of Mill Creek.

Aster Fremonti var. *Parishii* Gray, Synop. Fl. 1, pt. 2: 192.

Frequent on stream banks, Bear Valley (type) and Bluff Lake.

Erigeron concinnus T. & G. var. *aphanactis* Gray, Proc. Am. Acad. **6**: 540.

Abundant on dry slopes at Doble, Bear Valley.

Erigeron compositus Pursh var. *discoideus* Gray. Am. Journ. Sci. ser. 2, **33**: 540.

Summit of San Gorgonio Mountain, *Mrs. Wilder*.

Erigeron foliosus Nutt. Trans. Am. Philos. Soc. ser. 2, **7**: 309.

Occasional in dry soil in the Chaparral and Lower Transition Zones.

Erigeron striatus Greene, Bull. S. Cal. Acad. **1**: 39.

Houston Flat, in the Lower Transition Zone, *Shaw* (type) acc. Greene, *l. c.*

Psilocarphus globiferus Nutt. Trans. Am. Philos. Soc. ser. 2, **7**: 340.

On dry flats, Bear Valley.

Filago californica Nutt. Trans. Am. Philos. Soc. ser. 2, **7**: 405.
Infrequent in the Transition Zone.
Antennaria densa Greene, Leafl. **2**: 151.
Summit of San Gorgonio Mountain, *Abrams & McGregor*, type.
Antennaria dimorpha Nutt.; T. & G. Fl. **2**: 431.
Abundant, forming depressed mats, Bear Valley.
Antennaria marginata Greene, Pitt. **3**: 290.
South Fork of Santa Ana River, *Mrs. Wilder*. Not otherwise known in California.
Antennaria media Greene, Pitt. **3**: 289.
Summit of San Gorgonio Mountain, *Mrs. Wilder; Wright.*
Antennaria speciosa E. Nelson, Proc. Nat. Mus. **23**: 705.
Occasional on hillsides in the Upper Transition Zone. The type was collected in Bear Valley.
Gnaphalium californicum DC. Prodr. **6**: 224.
Frequent on dry banks in the Lower Chaparral Zone.
Gnaphalium microcephalum Nutt. Trans. Am. Philos. Soc. ser. 2, **7**: 404.
Frequent in cañons in the Lower Transition Zone.
Gnaphalium palustre Nutt. Trans. Am. Philos. Soc. ser. 2, **7**: 403.
Occasional on wet sandy banks in the Transition Zone.
Helianthus gracilentus Gray, Proc. Am. Acad. **11**: 77.
Frequent on dry banks in the Lower Chaparral Zone.
Verbesina dissita Gray, Proc. Am. Acad. **20**: 299.
Dobbs' Camp, Mill Creek Cañon, Upper Transition Zone, *Robertson.*
Madia dissitiflora T. & G. Fl. **2**: 405.
Occasional in cañons in the Lower Chaparral Zone.
Madia elegans Don in Lind. Bot. Reg. t. 1458.
Frequent in cañons in the Chaparral Zone.
Hemizonella minima var. *parvula* Hall, Univ. Cal. Publ. Bot. **3**: 148.
Frequent on dry ridges in the Lower Transition Zone.
Hemizonia Wheeleri Gray in Brew. & Wats. Bot. Cal. **1**: 617.
Abundant in open pine forests in the Upper Transition Zone.
Eriophyllum brachylepis Rydb. N. A. Fl. **34**: 88.
On dry slopes in open pine forest, Bear Valley, type station.
Eriophyllum confertiflorum var. *trifidum* Gray, Proc. Am. Acad. **19**: 25.
Frequent on dry slopes in the Lower Chaparral Zone.
Eriophyllum lanatum var. *obovatum* Hall, Univ. Cal. Publ. Bot. **3**: 186.
Frequent on dry slopes in open pine forest in the Transition Zone.
Hymenopappus lugens Greene, Pitt. **4**: 43.
Occasional in open pine forest in the Upper Transition Zone. Bear Valley is the type station.
Chaenactis carphoclinea Gray, Bot. Mex. Bound, 94.
A desert species ascending Cushenberry Cañon to the upper end of Bear Valley; infrequent.
Chaenactis santolinoides Greene, Bull. Torr. Club **9**: 117.
Frequent, mostly in stony places, in the Transition Zone. The type was collected in Little Bear Valley.
Hulsea heterochroma Gray, Proc. Am. Acad. **7**: 359.
San Gorgonio Mountain in the Canadian Zone; very seldom collected.

Hulsea vestita Gray, Proc. Am. Acad. **6**: 547.
Frequent in rocky and gravelly soil in the Upper Transition Zone, and in a depauperate form (var. *pygmaea* Gray) reaching the summit of San Gorgonio Mountain.

Helenium Bigelovii Gray, Pac. R. Rept. **4**: 107.
Occasional in meadows and along streams in the Upper Transition and Canadian Zones.

Achillea millefolium Linn. var. *lanulosa* Piper, Mazama **2**: 97. Yarrow.
Frequent in meadows in the Transition Zone.

Artemisia albula Wooten, cont. Nat. Herb. **16**: 193.
Common on dry, open flats about Doble, at the upper end of Bear Valley.

Artemisia californica Less. Linnaea **6**: 523.
On dry hills in the Lower Transition Zone.

Artemisia dracunculoides Pursh, Fl. **2**: 742.
Occasional on hillsides in the Chaparral Zone and in dry meadows in the Transition Zone.

Artemisia Rothrockii Gray in Brew. & Wats. Bot. Cal. **1**: 618.
In the Upper Transition Zone, *Vernon Bailey*, acc. Hall, Univ. Cal. Publ. Bot. **3**: 297.

Artemisia tridentata Nutt. Trans. Am. Philos. Soc. ser. 2, **7**: 398.
Abundant on dry open flats at the upper end of Bear Valley.

Raillardella argentea Gray in Brew. & Wats. Bot. Cal. **1**: 417.
In gravelly soil at the summit of San Gorgonio Mountain.

Arnica bernardina Greene, Pitt. **4**: 170.
Frequent in meadows in the Upper Transition and Canadian Zones. The type was from Bear Valley.

Tetradymia glabrata Gray, Pac. R. Rept. 2, pt. **2**: 122, t. 5.
Occasional in dry soil at the upper end of Bear Valley.

Senecio ionophyllus Greene, Pitt. **2**: 220.
Occasional in dry soil in the Upper Transition Zone.

Senecio ionophyllus Greene var. *bernardinus* Hall, Univ. Cal. Publ. Bot. **3**: 232.
Frequent in open pine forest in the Upper Transition Zone. Bear Valley is this type station.

Senecio ionophyllus Greene var. *sparsilobatus* Hall, Univ. Cal. Publ. Bot. **3**: 232.
Occasional in coniferous forest in the Canadian Zone. Barton Flats is the type station.

Senecio serra Hook. var. *sanctus* Hall, Univ. Cal. Publ. Bot. **3**: 230.
Occasional on moist north slopes in the Canadian Zone.

Senecio triangularis Hook. Fl. Bor. Am. **1**: 332, t. 115.
Occasional by stream banks and in wet places in the Canadian and Hudsonian Zones.

Carduus californicus Greene var. *bernardinus* Parish Hall, Univ. Cal. Publ. Bot. **3**: 241.
Frequent on dry hillsides in the Chaparral, and occasional in the Lower Transition Zone. Little Bear Valley is the type station.

Carduus Drummondii var. *acaulescens* Coville, Contr. Nat. Herb. **4**: 142.
Common and often abundant in dry meadows and flats in the Transition Zone.

BOOKS AND CURRENT LITERATURE

Soil Aeration and Plant Growth.—The importance of an adequate air supply to the roots of plants as a factor in their well-being constitutes the keynote to much of the very extensive field experimentation and observation on the behavior of cultivated plants which Howard and his colleagues have carried on for over a decade at Pusa, in the valley of the Ganges, and at Quetta in Indian Baluchistan.[1] The results of the work have been presented in several papers, which, although primarily of agricultural interest, are nevertheless of wide application in the general study of the relation of the growth and activities of roots to the soil environment and to the establishment of the species.

The work of Howard was carried on in the subtropical climate of northern India, but under widely different conditions as regards rainfall. At Pusa the rainfall is about 50 inches annually, with 85% occurring in June-September, during the monsoon. At Quetta, on the other hand, arid conditions prevail. The annual precipitation is about 10 inches only, most of which is in the cold season. The soil of the Gangetic plain is a fine alluvium which puddles easily. The soil at Quetta resembles that at Pusa but it is loess, sometimes mixed with alluvium, and it also easily runs together on wetting. From these general facts we are not surprised to learn that at Pusa the soil of the valley of the Ganges is saturated with water during the monsoon, and as a matter of fact after every severe storm. A similar but less marked condition occurs at Quetta, where unwise and ill-timed irrigation often causes the same results. It consequently happens that problems associated with the aeration of roots in both regions are of the first importance.

In general Howard's method may be said to consist in observations on the behavior of crops, including trees already established, during the periods of rains, or under conditions attending irrigation. This is supplemented by field experiments which deal largely with the effects of bettered aeration of the soil. Some of the observations and conclusions can be briefly given although a study of the papers will be necessary if a background for the results is desired.

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[1] Among the more important papers are the following: Howard, A. and Gabrielle L. C. Howard. Soil Ventilation. Bull. No. 52, Agric. Research Institute, Pusa. 1915. Howard, A. Soil Aeration in Agriculture. *Id.* Bull. No. 61. 1916.

At Pusa the following are some of the effects of poor soil aeration noted on the monsoon crops. The summer crops are heaviest when the monsoon rains are below the average and well distributed. The surface skin which forms on the soil as a result of these storms checks growth; breaking the crust benefits crops immediately. Howard concludes that in the Pusa region the want of sufficient air in the soil does infinitely more harm to the monsoon crops than the want of water. So far as the crops of winter are concerned, analogous results are to be seen. Although relatively small in amount, the rains of winter also cause the formation of a crust on the soil, which interferes with shoot growth, and when this crust is broken the activities of the shoot are restored to their normally healthy condition. Possibly, however, the most striking result of poor soil aeration on the growth of shoots was observed in connection with established trees. A resting period occurs during winter when leaf-fall is common. With the rise in temperature that takes place in February, new leaves are formed, and flowering and shoot growth occur. Rapid growth goes on until the hot weather supervenes. *At the commencement* of the monsoon phase another period of growth takes place, but with the saturation of the soil growth slows down or nearly ceases. It is not renewed until the end of the monsoon, when with the drying out of the soil better aeration results. Growth is then renewed for the second time and goes on until the advent of cold weather. Although the soil temperature is favorable in summer and there is an abundance of moisture, the vegetative activities are greatly diminished owing to the want of oxygen or the presence of a harmful amount of carbon di-oxide. The immediate effect of inadequate aeration of the soil is wilting, which has sometimes been treated as a disease.

Numerous cultural experiments show that the effects exerted on shoots by poor soil aeration affect the roots primarily. Thus, any method by which good aeration is produced restores the healthy condition of the crops, or prevents the injurious effects attendant on an inadequate air supply.

The fact that variation in soil aeration directly influences root growth is shown also in another manner by the behavior of *gram* under different soil conditions. When grown in three sorts of soil within 100 yards of each other and all well moistened, characteristic differences in the development of the root-systems of the plants were observed.

In heavy soil the roots were confined to the upper soil layers. In light soil the roots penetrated deeply and extended widely. In soil of an intermediate character the root development was also intermediate. The results were confirmed by the growth of *gram* with fragments of broken pottery added to the soil. In all cases soil which was provided with good aeration induced the type of root development that had already been observed in well aerated soil. Howard makes the interesting generalization that the distribution of *gram* as a crop follows the occurrence of well aerated soils.

The effects of inadequate aeration of the soil on crops of various kinds at Quetta are similar to the effects seen at Pusa, pointing to the undoubted general application of these conclusions in agriculture and in plant ecology. This has been pointed out recently[1] and additional research only serves to emphasize its importance.—W. A. CANNON.

THE BOOK OF FORESTRY.—The Book of Forestry[2] is not for the technical forester nor the ecologist, but for the lay reader who wants information about forestry and conservation. The author's aim is to "awaken the love of the forest in the heart of young America, and a realization that forestry is necessary for the comfort, health, and prosperity of future generations." The book is divided into two parts. In the first part the author crowds into 177 pages a mass of facts, figures and information covering forest influences, conservation of natural resources, forest growth, uses and properties of woods, silviculture, forest protection, timber estimating, lumbering, timber preservation and city forestry, with a chapter on the life of a forester thrown in. Under each heading enough is presented to give a reasonable idea of the subject. The second part contains brief descriptions and drawings of some of the more important American trees, and a key for identifying woods. In the appendix is given a table of uses of the principal American species, together with the range and maximum size of the tree, a sample volume table and log scale, a very short list of reference books in forestry, and a glossary of terms. A popular book does not require precision of statement, provided a correct impression is left with the reader, and, because of the difficulties inherent in this form of writing, we should overlook unimportant slips. But at the top of page 48, after saying that the lower branches soon die from lack of light, he adds, "and the next high wind or ice storm breaks them off, leaving the lower part of the trunk bare of branches." If this were the case, it would be comparatively simple to grow trees which would yield clear lumber in a reasonable length of time. But dead limbs persist so long after death that only in very old trees do we find clear lumber. However, the book appears to be unusually free from mistakes of this character.

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[1] Cannon, W. A. and E. E. Free. The Ecological Significance of Soil Aeration. Science, **44**: 178. 1917.

[2] Moon, P. F. The Book of Forestry, Pp. 315, figs. 64. New York, D. Appleton and Company, 1916. ($1.75).

Whoever has enjoyed Bruncken's admirable statement of the general principles of forestry[1] will be glad to have Professor Moon's book as a source of facts hitherto so scattered through government publications and periodic literature as to be inaccessible to the general public. The narrative form and amusing anecdotes will increase the size of the audience and the usefulness of the book.—BARRINGTON MOORE.

MEGASPOROPHYLLS OF CONIFERS.—A much needed comparative study of the vascular supply of cone-scales in all groups of conifers has been made by Miss Aase,[2] who finds that two processes have been at work in the evolution of the ovulate strobilus: (1) reduction in number of sporophylls in the strobilus, and (2) fusion of bract and ovuliferous scale, with or without a corresponding fusion of their vascular supplies. The diagrams accompanying this paper must be taken into account in any future discussion of the morphology of the cone.—M. A. CHRYSLER.

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[1] Bruncken, Ernest. North American Forests and Forestry. Pp. 262. New York, G. P. Putnam's Sons, 1908.

[2] Aase, H. C. Vascular Anatomy of the Megasporophylls of Conifers. Bot. Gaz. 60: 277–313. 1915.

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THE INDICATOR SIGNIFICANCE OF NATIVE VEGETATION IN THE DETERMINATION OF FOREST SITES

CLARENCE F. KORSTIAN

United States Forest Service, Ogden, Utah

Phytogeographers have long recognized certain variations in the native vegetation of given regions, while phytoecologists have only recently made notable advances in the correlation of the vegetation with the climatic and edaphic factors of the habitat. Within the last decade the physiological ecologist has been doing some excellent work on the correlation of the native vegetation with the crop-producing potentialities of the land, the results of which have a very practical application in present-day agriculture.

As a result of detailed studies in the Great Plains region of eastern Colorado, Shantz[1] concludes that the character of the native plant cover can be used as a reliable indicator of the conditions favorable or unfavorable for crop production, provided the relation between the vegetation and the environment is correctly interpreted. The correlations which exist in the Great Plains between the different types of vegetation and the physical characteristics of the corresponding types of land are described in detail. Shantz discusses at length the ways in which the native vegetation may be used in that region to determine the adaptability of the land for dry farming. The crop production on wire-grass land during favorable years is almost as good as on short-grass land and during normal and dry years much better crops are produced on wire-grass than on short-grass land. Using the native vegetation as an indicator of the

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[1] Shantz, H. L. Native Vegetation as an Indicator of the Capabilities of Land for Crop Production in the Great Plains Area, U. S. Dept. of Agri., Bur. of Plant Ind. Bul. 201, 100 pp. 1911.

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capabilities of crop production, the type of land that is characterized by the wire-grass association is classed as the most valuable agricultural land in eastern Colorado. That type of short-grass land which bears a considerable growth of wire-grass or *Psoralea* is classed with or very close to the wire-grass association land, since the presence of these plants indicate conditions intermediate between those of the typical wire-grass association and those indicated by the typical grama—buffalo-grass association. On new land where crops have not yet been produced, the character, growth, and condition of the native vegetation are the best possible indicators of crop production, either positive or negative, since plant growth is the ultimate criterion of the suitability of the physical environment.

Kearney and others[2] have gone still farther in the scientific study of native vegetation from the indicator point of view in suggesting the possibility of correlating the distribution of the vegetation with the physical and chemical properties of the soil and the utilization of such a correlation in the classification of the agricultural potentialities of the land. The investigations in the Great Basin of central Utah were directed toward the solution of the problems of what types of vegetation indicate conditions of soil moisture favorable or unfavorable to dry farming and what types indicate the presence or absence of alkaline salts in sufficient quantities to injure cultivated crops. The results of the studies in Tooele Valley show that the different types of native vegetation indicate the conditions of soil moisture and alkalinity of the land on which they are found and consequently provide a basis for estimating its potentialities for crop production. A good stand and growth of sagebrush (*Artemisia tridentata*) indicates land that is well adapted to both dry and irrigation farming. Where the stand of sagebrush is open and the growth poor the good soil is usually too shallow for profitable crop production, at least without irrigation. Dry farming is precarious on land covered by the Kochia (*Kochia*

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[2] Kearney, T. H., Briggs, L. J., Shantz, H. L., McLane, J. W. and Piemeisel, R. L. Indicator Significance of Vegetation in Tooele Valley, Utah. Journal of Agricultural Research 1: 365–417. 1914.

vestita) and shadscale (*Atriplex confertifolia*) associations, due to the shallowness of the alkali-free soil. Land occupied by the greasewood—shad-scale (*Sarcobatus vermiculatus* and *Atriplex confertifolia*) association is unsuitable for dry farming, but will produce good crops under irrigation.

The work on the correlation of the native vegetation with the crop-producing capabilities of the land has frequently suggested to the writer the possibility of utilizing the native vegetation in the determination of forest sites. In forestry, site is defined as an area considered as to its physical factors with reference to forest producing power; the combination of the climatic and edaphic conditions of an area or the forest habitat. For purposes of comparison the various sites are commonly segregated into site classes. Site class is a designation of the relative productive capacity or quality of different sites with reference to the species employed; the volume or the height produced at a given age being commonly used as the standard for classification. In the United States frequently only three classes are differentiated, designated by Roman numerals, quality I representing the most productive site class.

In a perusal of forestry literature one is impressed with the apparent fact that until only recently has much attention been given to the native vegetation, aside from the forest trees themselves, in the classification and segregation of forest sites. The majority of the references to the variation in the native herbaceous vegetation on different forest sites have been made incident to the describing of different sites or in characterizing their ground cover instead of from the indicator point of view.

The rather radical work of Cajander[3] must be cited as an exception to this statement. As a result of investigations of herbaceous and forest associations conducted in Finland, Germany, Austria-Hungary, Switzerland, Northern Russia and Siberia, Cajander concludes that, since no forester is in a position to determine definitely the limits of a dry or a moist soil, the difference in forest types must be based upon the character of the living ground cover as the clearest indicator of the site. Although Cajander admits that in virgin forests the composition of the forest itself correlated with the living ground cover is the best criterion of the physical conditions of growth, he further maintains that in forests which are under the influence of man the living ground cover alone may serve as a criterion and indicator of the physical conditions of the site. The latter statement is at variance with American ideas because of the failure to correlate the living ground cover with the different physical conditions of growth and the failure to appreciate the effect of the varying density of the forest cover on the living ground cover.

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[3] Cajander, A. K. Über Waldtypen, Helsingfors, 1909, Fennia 28, No. 2, 175 pp. Reviewed by Raphael Zon in Proc. Soc. Amer. Foresters 9: 119–125. 1914.

In pointing out the value of the native vegetation as a criterion of the potential productivity of land and its application to modern land classification, Pearson[4] maintains that a forest may be regarded as the aggregate effect or the summation of the physical conditions obtaining on the site on which it grows and that the consideration of the potentiality of the land need not be confined to the trees. Shrubs, herbs and even the lower forms of plant life may be correlated effectively with the physical factors of the site and also with the tree growth. Pearson concludes that the simpler and more reliable basis for the determination of the adaptability of the site for different crops consists in the use of characteristic forms of the native vegetation as indicators of the physical conditions of the site.

Mason[5] reports the abundance of huckleberry (*Vaccinium scoparium*) on the poorer lodgepole pine (*Pinus contorta*) sites of the Rocky Mountains. Alder (*Alnus tenuifolia*) and willow frequently occur as underbrush in moist situations of the same forest type.

Clements[6] in discussing the vegetative succession on burned-over areas in the lodgepole pine forest of the central Rocky

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[4] Pearson, G. A. What is the Proper Basis for the Classification of Forest Land into Types? Proc. Soc. Amer. Foresters **8**: 79–84. 1913.

[5] Mason, D. T. The Life History of Lodgepole Pine in the Rocky Mountains. U. S. Dept. of Agri. Bul. 154, pp. 11–12. 1915.

[6] Clements, F. E. The Life History of Lodgepole Burn Forests, U. S. Dept. of Agri., Forest Service Bul. 79, 56 pp. 1910.

Mountains, points out differences in the density and composition of the living ground cover varying with the favorableness or unfavorableness of the different lodgepole pine sites. The vegetative succession occurring on the burns during the course of the reëstablishment of the original forest cover shows, in an interesting way, the superseding of the xerophytically-inclined vegetation by vegetation possessing more mesophytic tendencies, until, as the site becomes more and more mesophytic, the original forest cover is eventually established. The relative mesophytism of the site at each of the more or less distinct stages of the succession is indicated by the native vegetation occurring on the site at that particular time. It is true, however, that the vegetation of any of the unstable stages of the succession cannot be regarded as being indicative of the latent potentiality of the site. The ultimate climax stage of the succession must have been reached before much importance can be attached to the indicator significance of the native vegetation in the determination of site, especially from the standpoint of the forester.

Zon[7] in describing the forest types in which balsam fir (*Abies balsamea*) occurs, states that sphagnum and other mosses are the principal species which comprise the living ground cover of the swamp type. Fern moss replaces sphagnum as the predominating ground cover of the flat type. Ferns and certain flowering plants become the conspicuous herbaceous plants of the hardwood slope type in which balsam fir is reported as attaining its best individual development although the best stand development occurs in the flat type. The descriptions of the forest types are supported by lists which show the relative proportion of the different species and the character of the vegetation comprising the living ground cover of the swamp, flat, and hardwood slope types.

Hole and Singh[8] in studying the soil types and native vegetation of the sal forests in the vicinity of the Forest Research

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[7] Zon, Raphael. Balsam Fir. U. S. Dept. of Agri. Bul. 55, pp. 4–7. 1914.

[8] Hole, R. S. and Singh, Puran. Oecology of Sal (*Shorea robusta*); Part I, Soil composition, soil-moisture, soil-aeration. Indian Forest Records, Vol. V, Part IV, pp. 13–14. 1914.

Institute, Dehra Dun, India, consider three principal soil types, each of which is characterized by distinct types of vegetation. The poorer soils, containing a large percentage of sand and a relatively small amount of silt, are frequently shallow, with gravel and boulders below. These soils are essentially dry and bear a dry forest with *Acacia catechu* and *Dalbergia sissoo* prominent, or grassland with *Saccharum munja* dominant. The well-aerated deep loams are covered with a sal forest or grassland with *Saccharum narenga* (often mixed with *Anthistiria gigantea* subsp. *arundinacea*) dominant. The poorly-aerated deep loams, differing from the well-aerated soils in containing more clay and silt, in actually being heavier, or in having the water-table nearer the surface, are characterized by a moist forest with *Betula frondosa*, *Stereospermum suaveolens*, *Terminalia*, *Cedrela toona* and others, or grassland with *Erianthus ravennae* (often mixed with *Anthistiria gigantea* subsp. *villosa*) dominant.

More recent work by the same investigators[9] indicates that the dominant grasses on an area are excellent indicators of the soil conditions. In northern India, where *Saccharum narenga* and *Anthistiria gigantea* subsp. *arundinacea* tend to be dominant, the soil moisture and aeration are suitable for the best development of sal and the moist type of sal forest prevails, in the shaded parts of which the reproduction suffers from poor soil aeration. Such grasses as *Saccharum munja*, *Saccharum spontaneum*, *Eragrostis cynosuroides*, *Imperata arundinacea*, *Vetiveria zizanioides*, *Andropogon contortus* and *Ischaemum angustifolium* usually indicate a soil too dry, or too heavy, for the best development of sal and such forests as occur are of the dry sal type.

Pearson[10], in discussing the effect of a cover of aspen (*Populus tremuloides*) upon the establishment of Douglas fir (*Pseudotsuga taxifolia*), has made a very interesting comparison of two different sites which occur at the transition between the Douglas fir and western yellow pine (*Pinus ponderosa*) types at an elevation of 8700 feet on the San Francisco Mountains in northern Arizona. Both sites had the same exposure but one was aspen-covered and the other was in the open. After making detailed studies of the physical factors of the two adjacent sites, the survival and development of Douglas fir planted on both sites and the correlation of the native vegetation occurring on the sites the conclusion was drawn that the open sites, due to their greater severity, should doubtless be reforested with western yellow pine (*Pinus ponderosa*) while the aspen-covered areas should be planted with Douglas fir. The aspen thickets supported a luxuriant growth of broad-leaved mesophytic herbaceous plants, such as *Frasera scabra, Pteridium aquilinum* and *Verbascum thapsus*, while grasses (*Muhlenbergia gracilis, Festuca arizonica, Festuca pseudovina*, and *Bromus polyanthus*) predominated in the openings. The growth of all herbaceous plants was invariably more luxuriant under the aspen than in the open.

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[9] Hole, R. S. and Singh, Puran. Oecology of Sal (*Shorea robusta*); Part II, Seedling Reproduction in Natural Forests and its Improvement. Indian Forest Records, Vol. V, Part IV, pp. 83–84. 1916.

[10] Pearson, G. A. The Rôle of Aspen in the Reforestation of Mountain Burns in Arizona and New Mexico. The Plant World **17**: 249–260. 1914.

Shreve[11] reports a rather marked variation in the distribution of the vegetation occurring in a forest of *Pinus arizonica* on the Santa Catalina Mountains in southern Arizona. Throughout the pine forest are to be found a large number of herbaceous perennials, the greater majority of which accompany the closed stands of pine. The occurrence of another large group of plants is confined to the near proximity of streams and stream-courses. In the dense shade of the evergreen-oak woodland *Pteris aquilina* is reported as being common, and it again becomes common in the pine forest above 7500 feet, but is infrequent in the lower portion of the forest region. *Alnus acuminata, Acer interius,* and *Quercus submollis* become frequent along streams at about 6800 feet. Herbaceous plants are reported as being found in increasing numbers at or near the banks of streams between 6000 and 7400 feet, among which may be mentioned *Juncus arizonicus, Aquilegia chrysantha, Thalictrum fendleri* var. *wrightii, Scrophularia* sp., *Trifolium pinetorum, Fragaria ovalis, Poten-*

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[11] Shreve, Forrest. The Vegetation of a Desert Mountain Range as Conditioned by Climatic Factors, Pub. 217, Carnegie Inst. Wash. 112 pp. 1915.

tilla thurberi, *Hypericum formosum*, *Lobelia gruina*, *Agrimonia brittoniana* var. *occidentalis*, *Gaura suffulta*, and *Tagetes lemmoni*.

Weaver[12] has recorded the variation in the vegetative undergrowth with a change of the site in the cedar (*Thuja plicata*) forest on the Thatuna Hills in southeastern Washington. Near the streams the forest floor is covered with *Athyrium cyclosorum* which gives way farther back to a rather dense growth of *Rubus parviflorus*, *Vagnera amplexicaulis*, *Tiarella unifoliata*, *Trillium ovatum*, *Clintonia uniflora*, *Disporum majus*, *Pyrola* sp., *Actaea spicata arguta*, and *Coptis occidentalis*, *Viola* sp., *Streptopus amplexifolius*, and *Phegopteris dryopteris*. These together with the cedar seedlings comprise the characteristic undergrowth, while farther up the slope there is almost no living ground cover.

Fuller[13] notes the relation between the mesophytism of a site and the undergrowth in some comparatively undisturbed beech-maple forests about 45 miles southeast of Chicago, when he states that the lower evaporation in the ravine may be a sufficient explanation for the presence upon its slopes of a much greater abundance of such delicate forms as *Dicentra canadensis*, *D. cucullaria*, *Impatiens biflora*, and *Asplenium angustifolium*.

Peters,[14] as a result of observations made in Northampton County, Pennsylvania as early as 1806, calls attention to the fact that the timber alone is not always an invariable indicator of the capabilities of the land. Hemlock (*Tsuga canadensis*), white pine (*Pinus strobus*), and pitch pine (*Pinus rigida*) were reported as occurring on deep, fertile loams as well as on the thinnest, sterile, sandy soils. It is readily seen that the vegetation must be properly correlated with its habitat and the relation between vegetation and environment must be correctly interpreted.

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[12] Weaver, John E. Evaporation and Plant Succession in Southeastern Washington and Adjacent Idaho. The Plant World **17**: 273-294. 1914.

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It should be clearly recognized that the use of native vegetation as an indicator of forest sites is not without certain limitations. The use of native shrubby, and particularly herbaceous, vegetation as forest site indicators is not exactly comparable to using native open-land vegetation as an indicator of the crop productivity of an open-land site. In the case of the forest site the presence or absence of an over-wood must be recognized as an influential factor. The use of shrubby and herbaceous vegetation as indicators of forest sites encounters more obstacles in the dense Douglas fir, lodgepole pine, and Engelmann spruce (*Picea engelmanni*) forests than in the comparatively open western yellow pine forests. In the dense forests herbaceous plants are rather scarce except in partial openings or where the stand is below its normal density. The vegetation of the denser forests also varies in its composition from place to place, not only according to the favorableness of the site, but also with the density of the crown cover and consequently the amount of shade in the forest. The floor of the fir, spruce and lodgepole pine forests is more heavily and continuously shaded than that of the densest stands of western yellow pine. The factor of shade is of great importance in conditioning the character of the shrubby and herbaceous vegetation of dense forests.

While engaged in the remeasurement of a set of permanent sample plots aggregating 26.4 acres on the San Mateo Division of the Datil National Forest in west central New Mexico in the summer of 1915 the writer was impressed with the variation in the vegetation occurring on the different western yellow pine sites. The San Mateo Mountain range extends in a general north and south direction and rises to a height of 9500 to 10,500 feet above sea level. The north and west portions of the mountains slope quite gradually to the adjacent rolling plains. The east and south portions of the range break off quite abruptly to the plains. The majority of the steeper east and south aspects bear such species as *Juniperus monosperma*, *J. pachyphloea*, *Pinus edulis*, *Quercus chry-*

solepis, *Q. undulata*, and *Cercocarpus breviflorus*, while western yellow pine predominates on the more gradual slopes which are more retentive of soil moisture. In the more protected and more moist situations, such as cañon bottoms and north slopes at the higher elevations, *Pseudotsuga taxifolia*, *Abies concolor*, *Pinus flexilis*, *Picea engelmanni*, *P. parryana*, and *Populus tremuloides* are found. Western yellow pine occupies the more gradual slopes and situations at the intermediate elevations. A rather erratic altitudinal distribution of the species is evident in the San Mateo Mountains. At the elevation of the plots, which is approximately 8000 feet above sea level the cañon bottoms, north slopes and lower south slopes are occupied by an almost pure stand of western yellow pine which is typical of the San Mateo Mountains, while a belt of the more xerophytic species is frequently found on the more exposed upper south slopes above the western yellow pine.

The plots were established in 1910 with the principal object of determining the rate of growth and decadence of western yellow pine in this locality. They are located in the cañon bottoms and on the slopes, the gradients of which vary from 3 to 50%. Prior to the establishment of the plots the area had been cut-over, removing many of the mature and over-mature trees and a large proportion of the merchantable material. A modified selection system of cutting to a variable diameter limit was followed when the timber was marked. Occasionally large merchantable trees were reserved as seed or fire insurance trees or to maintain the general continuity of the forest cover. When the plots were established in 1910, the diameters and total heights of all trees 3.6 inches or more in diameter at 4.5 feet above the ground were measured. Each tree was described, especially with reference to its vigor, health or decadence, its crown class and all diseases, defects or abnormalities were noted. The plots were remeasured and examined in 1915, thus giving their history for the intervening five-year period.

Two well-recognized forms of *Pinus ponderosa* are distinguished, "black jack" and "yellow pine," based on age, rate of growth, and the resulting color of the bark. The term "black jack" applies to the young, vigorous trees under 125 to 150 years old which are characterized by a dark, almost black, or dark brown, narrow-furrowed bark. The "yellow pine" form comprises the older trees which are characterized by a yellowish or reddish brown, widely furrowed bark. A marked difference occurs between the form and volume of "black jacks" and "yellow pines." The average "black jack" has a greater taper, a more rapid rate of growth and approximately 10% smaller cubic volume than the average "yellow pine" of the same diameter and height, which are the main reasons for the segregation of "black jack" and "yellow pine" by technical foresters.

Two distinct western yellow pine sites were very readily recognized through apparent differences in the composition, density, rate of growth, and vigor of the forest and the corresponding differences in the shrubby and herbaceous vegetation. The soil of Site I, which occupies the cañon bottoms and the protected north slopes, is a deep gravelly clay loam containing considerable amounts of organic matter and is consequently comparatively retentive of soil moisture. Site II, which has a shallow well-drained gravelly soil containing little organic matter, is found on the ridge-tops and exposed south slopes. At the time of the 1915 examination the two sites were segregated and each was mapped separately. Approximately 16.0 acres were classed as Site I, while 10.4 acres fell into Site II.

The growth data were segregated in separate compilations for each site and for the two forms of western yellow pine.[15] The total volume growth or increment of all trees measured was computed for the five-year period. The total volumes were computed by applying a volume table based on diameter and total height to the dimensions of each tree at each time of measurement. The difference between the total volumes at each time of measurement represents the periodic increment and the average volume growth per year during the period considered is the periodic annual increment. Table 1 shows the increment of both forms of western yellow pine for Sites I and II. The data are significant in that they indicate the relative productivity of the two sites and the variability of the increment depending on the kind and amount of growing stock. The data given in table 1 represent the net increment since the volumes of all trees which died during the quinquennium were considered as negative increment and the volumes of all trees growing into the 4-inch class as positive increment. The fact that the plots were cut-over in 1910 under Forest Service regulations accounts for the relatively small amount of merchantable growing stock. The abundance of poles from 4 to 10 inches in diameter breast high which were left on the area accounts for the proportionately greater cubic volume of the growing stock. Since a number of trees grew into the merchantable class during

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[15] The writer is indebted to Forest Examiners H. B. Wales and J. W. Stokes for assistance rendered in the collection and compilation of the growth data presented in this paper.

TABLE 1

Increment data for 26.4 acres of typical western yellow pine in the San Mateo Mountains of west central New Mexico, based on five years' growth

	TOTAL MERCHANTABLE VOLUME*		MERCHANTABLE INCREMENT, 1910–1915			TOTAL CUBIC VOLUME†		CUBIC INCREMENT, 1910–1915		
	1910	1915	Periodic	Periodic annual	Annual, per acre	1910	1915	Periodic	Periodic annual	Annual, per acre
	feet B. M.	*feet B. M.*	*feet B. M.*	*feet B. M.*	*feet B. M.*	*cu. ft.*	*cu. ft.*	*cu. ft.*	*cu. ft.*	*cu. ft.*
Site I										
"Black Jack"....	16,720	22,700	5,980	1,196	75	9,723.4	10,872.3	1,148.9	229.8	14.4
"Yellow Pine"..	22,250	26,690	4,440	888	55	4,872.5	5,730.7	858.2	171.6	10.7
Total for species...	38,970	49,390	10,420	2,084	130	14,595.9	16,603.0	2,007.1	401.4	25.1
Site II										
"Black Jack"....	3,110	3,720	610	122	12	2,955.5	3,147.1	191.6	38.3	3.7
"Yellow Pine"...	8,040	10,450	2,410	482	46	2,642.6	3,244.7	602.1	120.4	11.6
Total for species...	11,150	14,170	3,020	604	58	5,598.1	6,391.8	793.7	158.7	15.3

* Includes the volumes in feet, board measure, of all western yellow pine trees 12 inches and over in diameter breast high.

† Includes the volumes in cubic feet of all western yellow pine trees 3.6 inches and over in diameter breast high.

the quinquennium and are included for the first time in the 1915 board-measure computations, the annual increment per acre as shown in board feet is perhaps somewhat greater than the mean annual increment would be for a longer period. The annual increment per acre in cubic feet is therefore considered as a better criterion of the relative productivity of each site. It is noteworthy that Site I produced 25.1 cubic feet per acre per year as against 15.3 cubic feet for Site II or, in other words Site I produced a cubic volume of 64% more than Site II during the same five-year period.

It is also interesting to compare the average breast high diameter growth of both forms of western yellow pine on the two sites. "Black jack" averaged 0.85 inch on Site I while the diameter growth of this form on Site II was only 0.71 inch. The breast high diameter growth of "yellow pine" on Site I averaged 0.75 inch, while on Site II it averaged only 0.54 inch. The mean diameter growth for the species as a whole amounted to 0.83 inch on Site I and 0.68 inch on Site II.

During the course of the compilation of the pertinent data presented above an opportunity was offered to compare the average increment per tree of the different crown classes. All of the trees on the permanent sample plots were classified according to their dominance or relative position in the crown cover, into the following crown classes:

X = *Isolated:* Trees growing in the open which do not form a contiguous part of the regular forest canopy.
D = *Dominant:* Trees with crowns extending above the general level of the forest canopy and receiving full light from above and partly from the side; larger than the average trees in the stand, and with crowns well-developed but possibly somewhat crowded.
C = *Codominant:* Trees with crowns forming the general level of the forest canopy and receiving full light from above but comparatively little from the sides; usually with medium-sized crowns more or less crowded on the sides.
I = *Intermediate:* Trees with crowns below, but still extending into the general level of the forest canopy, receiving a little

direct light from above but none from the sides, usually with small crowns considerably crowded on the sides.

S = *Suppressed:* Trees with crowns below the general level of the forest canopy and receiving no direct light either from above or from the sides; usually with small, poorly developed crowns.

Table 2 shows the average increment per tree for the different crown classes on Sites I and II, only those trees being included which were living and were measured in 1910 and 1915. The greater apparent increment of the dominant crown class might be explained by the fact that in the X class a greater amount of limb-wood is produced, while in the dominant class, due to their relative position in the forest, there is a stimulation in the production of body-wood which is the portion of the tree measured to determine the increment. When the individual trees, the component parts of an aggregate stand, are given separate consideration it is evident that not only the effects of the physical site are revealed in the increment but also the effects of the individual's associates, especially their influence on the amount of light the individual receives or the amount of growing space available for its use. Although the average increment per tree varies directly with the favorableness of the conditions of the site, the writer does not wish to leave the impression that crown form may be regarded as an expression of site quality.

TABLE 2

Periodic cubic increment of western yellow pine segregated by crown classes for Sites I and II

CROWN CLASS	SITE I			SITE II			COMPARATIVE INCREMENT OF SITE II WITH SITE I
	Basis	Total periodic increment	Periodic increment per tree	Basis	Total periodic increment	Periodic increment per tree	
	no. of trees	*cu. ft.*	*cu. ft.*	*no. of trees*	*cu. ft.*	*cu. ft.*	*per cent*
X	230	622.3	2.70	204	314.1	1.54	57
D	168	617.8	3.68	87	184.4	2.12	57
C	411	721.4	1.75	247	268.9	1.08	61
I	119	69.9	.58	74	29.5	.39	67
S	14	4.4	.31	5	1.2	.24	77

It is true that crown form reflects the growing conditions as determined by competition but competition cannot be regarded as a site factor.

The differences in the native vegetation on the two different sites were so apparent that the writer immediately conceived the idea that it could be correlated with increment and used as an additional criterion in the determination of the productivity of a given forest site.

The vegetation on a number of 5 by 10-foot quadrats was listed in addition to that on the regular permanent reproduction plots of the same size, which were instituted with the primary object of studying the establishment of natural reproduction on the cut-over areas. Although the plots had been cut-over in 1910, the logging operation which was conducted under Forest Service regulations did not destroy the continuity of the forest canopy sufficiently to noticeably interfere with the stabilized climax vegetation since the virgin western yellow pine forest was originally comparatively open and park-like. The vegetation which was found on these list quadrats is systematically summarized in table 3, showing for the cañon bottoms, the north slopes, south slopes and ridge tops the percentage of the quadrats on which each species was found. The arrangement of the families is essentially an adaptation of Engler and Prantl's "Die Natürlichen Pflanzenfamilien" as used in the United States National Herbarium, which aims to indicate something of the natural developmental relationships of the families by proceeding from the simpler to the more complex. The writer desires to express his indebtedness to Prof. J. J. Thornber of the University of Arizona and Grazing Examiner R. R. Hill of the United States Forest Service for determining numerous plants and for verifying the list. A perusal of the list shows marked differences in the individuality of the vegetation of the two sites. Site I is shown to produce such typical mesophytes as *Mnium* sp., *Agrostis hiemalis*, *Bromus polyanthus*, *Muhlenbergia wrightii*, *Populus tremuloides*, *Arenaria confusa*, *Cerastium longipedunculatum*, *Silene laciniata*, *Aquilegia chrysantha*, *Thalictrum wrightii*, *Draba helleriana*, *Potentilla atrorubens*, *P. crinita*, *Rosa fendleri*,

TABLE 3

Systematic summary of vegetation on fifty-three list quadrats taken at random on the San Mateo Division of the Datil National Forest, New Mexico

	PER CENT OF QUADRATS ON WHICH SPECIES OCCUR					
	Cañon bottom (12 quadrats)	North slope (13 quadrats)	Total site I (25 quadrats)	South slope (23 quadrats)	Ridge top (5 quadrats)	Total site II (28 quadrats)
BRYACEAE						
Mnium sp	8	15	12	0	0	0
POACEAE						
Agropyron tenerum Vasey	8	0	4	0	0	0
Agrostis hiemalis (Walt.) B. S. P.	25	0	12	0	0	0
Blepharoneuron tricholepis (Torr.) Nash	17	0	8	56	20	50
Bromus polyanthus Shear	8	0	4	0	0	0
Bromus porteri (Coult.) Nash	50	69	60	30	0	25
Festuca arizonica Vasey	17	15	16	0	20	4
Koeleria cristata (L.) Pers	42	69	56	74	100	64
Muhlenbergia gracilis (H. B. K.) Trin	33	54	44	65	40	61
Muhlenbergia wrightii Vasey	8	0	4	0	0	0
Poa rupicola Nash	0	0	0	39	0	32
Sitanion brevifolium J. G. Smith	17	31	24	17	80	29
Sporobolus ramulosus (H. B. K.) Kunth	17	15	16	13	0	11
CYPERACEAE						
Cyperus fendlerianus Boeckel	17	23	20	61	20	54
COMMELINACEAE						
Commelina dianthifolia Delile	0	0	0	0	20	4
LILIACEAE						
Yucca sp	0	0	0	4	0	4
ORCHIDACEAE						
Achroanthes montana (Rothr.) Greene	0	0	0	0	20	4
SALICACEAE						
Populus tremuloides Michx	8	8	8	0	0	0
FAGACEAE						
Quercus gambelii Nutt	0	46	24	9	20	11
Quercus grisea Liebm	0	0	0	9	40	14
POLYGONACEAE						
Eriogonum alatum Torr	0	8	4	22	40	25
Eriogonum jamesii Benth	0	8	4	0	20	4
Polygonum douglasii Greene	0	0	0	4	0	4
CHENOPODIACEAE						
Chenopodiumob longifolium (S. Wats.) Rydb	0	8	4	0	0	0

TABLE 3—Continued

	PER CENT OF QUADRATS ON WHICH SPECIES OCCUR					
	Cañon bottom (12 quadrats)	North slope (13 quadrats)	Total site I (25 quadrats)	South slope (23 quadrats)	Ridge top (5 quadrats)	Total site II (28 quadrats)
NYCTAGINACEAE						
Allionia divaricata Rydb.	0	0	0	4	0	4
PORTULACACEAE						
Portulaca oleracea L.	0	0	0	13	0	11
SILENACEAE.						
Arenaria confusa Rydb.	17	31	24	0	0	0
Cerastium longipedunculatum Muhl.	8	0	4	0	0	0
Silene laciniata Cav.	0	23	12	0	0	0
Silene pringlei S. Wats.	0	8	4	9	20	11
RANUNCULACEAE						
Aquilegia chrysantha A. Gray	8	0	4	0	0	0
Thalictrum wrightii A. Gray	0	31	16	0	0	0
BRASSICACEAE						
Draba helleriana Greene	0	8	4	0	0	0
Erysimum elatum Nutt.	8	0	4	4	0	4
Heterothrix longifolia (Benth.) Rydb.	0	0	0	17	0	14
ROSACEAE						
Cercocarpus breviflorus A. Gray	0	0	0	9	0	7
Fragaria bracteata Heller	8	31	20	4	0	4
Potentilla atrorubens Rydb.	8	0	4	0	0	0
Potentilla crinita A. Gray	8	0	4	0	0	0
Rosa fendleri Crép.	33	38	36	0	0	0
FABACEAE						
Anisolotus wrightii (A. Gray) Rydb.	8	8	8	26	60	32
Aragallus lambertii Greene	8	23	16	0	20	4
Astragalus accumbens Sheld.	8	38	24	30	80	39
Lathyrus graminifolius (S. Wats.) White	17	62	40	35	60	39
Phaseolus angustissimus A. Gray	0	8	4	0	0	0
Vicia americana Muhl.	17	38	28	26	0	21
OXALIDACEAE						
Oxalis stricta L.	0	8	4	0	0	0
GERANIACEAE						
Geranium fremontii Torr.	25	8	16	4	0	4
Geranium richardsonii Fisch. & Trautv.	0	8	4	0	0	0
LINACEAE						
Linum neomexicanum Greene	0	8	4	0	0	0
EUPHORBIACEAE						
Euphorbia fendleri Torr. & Gray	0	8	4	0	0	0

TABLE 3—Continued

	PER CENT OF QUADRATS ON WHICH SPECIES OCCUR					
	Cañon bottom (12 quadrats)	North slope (13 quadrats)	Total site I (25 quadrats)	South slope (23 quadrats)	Ridge top (5 quadrats)	Total site II (28 quadrats)
RHAMNACEAE						
Ceanothus fendleri A. Gray	17	0	8	9	40	14
Viola neomexicana Greene	0	23	16	0	0	0
APIACEAE						
Pseudocymopterus tenuifolius (A. Gray) Rydb	0	38	20	48	60	50
GENTIANACEAE						
Amarella scopulorum Greene	0	15	8	0	0	0
Gentiana bigelovii A. Gray	8	8	8	0	0	0
POLEMONICACEAE						
Gilia greeneana Woot. & Standl	0	0	0	22	0	18
BORAGINACEAE						
Lithospermum multiflorum Torr	8	23	16	4	20	7
MENTHACEAE						
Prunella vulgaris L	8	0	4	0	0	0
SCROPHULARIACEAE						
Castilleja trinervis Rydb	16	54	36	0	20	4
Mimulus langsdorfii Don	8	0	4	0	0	0
Pentstemon gracilis Nutt	0	15	8	26	40	29
Pentstemon virgatus A. Gray	8	8	8	0	0	0
CAMPANULACEAE						
Campanula petiolata A. DC	8	8	8	0	0	0
ASTERACEAE						
Achillea lanulosa Nutt	33	69	52	4	0	4
Artemesia forwoodii S. Wats	8	0	4	30	0	25
Artemesia mexicana Willd	17	46	32	0	0	0
Artemesia sp	0	8	4	4	40	11
Chrysopsis villosa (Pursh) Hook	8	15	12	44	20	43
Coleosanthus petiolaris (A. Gray) Greene	0	0	0	4	0	4
Conyza coulteri A. Gray	0	0	0	4	0	4
Dugaldea hoopesii (A. Gray) Rydb	25	15	20	56	100	64
Erigeron divergens Torr. & Gray	8	0	4	0	0	0
Gymnolomia multiflora (Nutt.) Benth & Hook	17	0	8	4	20	7
Hymenopappus mexicanus A. Gray	0	8	4	17	20	18
Hymenopappus radiatus Rose	0	0	0	13	0	11
Machaeranthera aquifolia Greene	42	77	60	35	20	32
Oreochrysum parryi (A. Gray) Rydb?	0	0	0	17	20	18
Senecio quaerens Greene?	0	0	0	13	20	14
Solidago neomexicana (A. Gray) Woot. & Stand	0	38	20	0	0	0
Stevia serrata Cav	17	0	8	0	0	0
Villanova dissecta (A. Gray) Rydb	25	0	12	9	0	7

Geranium richardsonii, Viola neomexicana, Amarella scopulorum, Gentiana bigelowii, Prunella vulgaris, Mimulus langsdorfii, Penstemon virgatus, Campanula petiolata, and *Solidago neomexicana.* Site II bears such transitory species and xerophytes as *Poa rupicola, Commelina dianthifolia, Yucca* sp., *Quercus grisea, Portulaca oleracea, Heterothrix longifolia, Cercocarpus breviflorus,* and *Hymenopappus radiatus.* The moss (*Mnium* sp.) was only found in cool, moist and shaded situations, thereby indicating unusually favorable site conditions. The monkey flower (*Mimulus langsdorfii*) was the only plant which was confined to the proximity of water, indicating excessive soil moisture conditions.

Practically all of the species listed as occurring entirely on Site II, which do not overlap on other sites, were found in hot, dry and unshaded situations and might be regarded tentatively as indicators of poor western yellow pine sites in the San Mateo Mountains. The mesophytes listed as possible Site I indicators were not found on poorer sites in this locality. However, it may be true that further detailed studies in the San Mateo Mountains might require a different listing of the vegetation than that here given. A number of the species listed as occurring on only one site are, to the writer's personal knowledge, known to occur on different sites in other parts of the Southwest. The vegetation on Site II was comparatively sparse and more open than on Site I where it was also more luxuriant and vigorous. Those species which were found to overlap on both sites normally made their optimum development on Site I. Approximately twice as many species were found on Site I as on Site II. It is therefore with some reluctance that certain opinions are advanced regarding the indicator significance of the natural vegetation. The writer is not attempting, however, to state that certain species are positive site indicators or that others are negative indicators. The rather superficial nature of the field observations will only permit of a few more or less general statements concerning the latent possibilities in the use of the native vegetation in the classification of forest sites and in the determination of their productivity.

In studying the indicator significance of the native vegetation it is necessary to go directly to the individual species instead of attempting to stop at the association, society, or community, since the vegetation as an integral is composed of individual species and in intergrating the vegetation it must be remembered that the behavior of the vegetation is a resultant function of the behavior of the component species. It is impossible in arid and semi-arid regions having many diverse biological growth forms, to select a group of plants which may be regarded as associates without finding that the association may have been disorganized elsewhere and that some of the individuals enter into other associations as component parts.

It is freely admitted that the best ultimate criterion of site quality is the increment of the aborescent species concerned, as judged by the measurement of an approximately fully stocked stand. In cases where the increment data are rather meager or are entirely lacking the native vegetation present should serve as a valuable criterion of site for those species addicted to growing in rather open, park-like stands, such as western yellow pine. In this connection it should be remembered that a plant rarely requires more than a few years at most to reach the adult form, while the forest often requires a century or even two in which to reach maturity. The writer believes that the native vegetation found on deforested areas may be considered as a criterion of the latent potentialities of the site for forest production provided the vegetation has not been too severely and too recently disturbed and that the more important phases of the successional series are properly understood.

Studies are under way at the Utah Forest Experiment Station in central Utah, the object of which is to determine the feasibility of using native plants as indicators of suitable forest planting sites. By making detailed studies of the root systems and subterranean moisture-absorbing surfaces of the typical herbaceous, shrubby and arborescent species of each important association, the value of the native vegetation as indicators of those climatic and edaphic conditions under which the important coniferous species may be planted successfully should be determined. The studies of the depth and character of the root systems will lead to the determination of the different successional stages of the native vegetation on burned-over or cut-over land. It is very probable that the sudden removal of the vegetative cover renders the site less favorable for the successful establishment and optimum development of the climax species and the more favorable for the invasion of species normally occurring on poorer sites at lower elevations.

The fundamental study of forest planting sites logically resolves itself into three categories: (1) the empirical establishment of plantations and the observation and study of their survival and subsequent development, (2) the measurement and study of the most important physical factors of the site, such as the available soil moisture or growth water and evaporation, and (3) the indicator significance of the native vegetation occurring on the sites implying a very careful correlation of all three phases, especially the correlation of the species with the physical conditions which produce them, and a study of the relative transpiration of the natural and planted vegetation.

It is readily conceivable that site studies of this character will be of the utmost value in explaining the presence or absence of tree growth on certain areas, in the judicious selection of the proper species and sites in the reforestation of much of the denuded forest land of the United States, and in establishing a working basis for the classification of the potential productivity of forest lands. Only after considering the relative agricultural and forest productivity of the land on a combined scientific and economic basis, can a positive conclusion be reached that its greatest utility lies in its use for forestry or for agricultural purposes.

THE ADAPTATION OF TRUOG'S METHOD FOR THE DETERMINATION OF CARBON DIOXIDE TO PLANT RESPIRATION STUDIES[1]

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In plant studies involving the phenomena known as respiration, there is often occasion to determine the quantity of carbon dioxide respired. This is regarded as an accurate, and at the same time the most readily determinable, index of respiratory activity available in laboratories not provided with an elaborate respiration calorimeter. Satisfactory methods for the determination of carbon dioxide are accordingly of interest to plant physiologists and biochemists who are concerned with this phase of phytochemistry.

In the preliminary work on the study of the respiration of stored grain which the writer is conducting, it became evident that there were two requisites which the method for the determination of carbon dioxide must satisfy in order to be applicable to this purpose. First, since the plant tissues are constantly respiring, in determining the rate of respiration it is necessary that the accumulated carbon dioxide be rapidly removed from the respiration chamber. Second, the method must accommodate the wide variations in the quantity of carbon dioxide to be determined, without materially sacrificing accuracy.

The customary, and most convenient method of determining the quantity of carbon dioxide in the atmosphere of the respiration chamber, is to sweep CO_2-free air through it, and absorb the respired CO_2 in some form of absorption train. The conventional absorption train, in which small potash bulbs are employed, is of limited value because of the slow rate at which the gases must be passed through it. It cannot be employed where the time element is significant. The method of Truog[2] in which the carbon dioxide is absorbed in a measured quantity of $\frac{N}{4}$ $Ba(OH)_2$ solution contained in a special absorption tower, and the residual barium hydroxide titrated against a standard HCl solution, seemed best adapted to this purpose. The advantages of this method, together with a discussion of titrimetric methods, are presented by Truog. In assembling the apparatus certain difficulties were encountered, however, and an attempt was made to overcome them. Thus the original form of absorption tower did not provide an adequate means for transferring the standard $Ba(OH)_2$ solution, and CO_2-free water from the stock bottles to the absorption tower without exposing them to the atmosphere. An automatic pipette was accordingly constructed which was connected to both the stock bottle and the tower in such a manner that the $Ba(OH)_2$ solution could be transferred and measured through a closed system protected from the laboratory air by soda-lime tubes. A convenient arrangement for rendering the wash-water free from CO_2 without disconnecting the reservoir was also assembled. These additions rendered the apparatus more efficient for plant respiration studies, and they are described in detail in this paper.

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[1] Published with the approval of the Director as Paper No. 58 of the Journal Series of the Minnesota Agricultural Experiment Station.

DESCRIPTION OF THE APPARATUS

The complete apparatus is illustrated in the accompanying figure. The absorption flask and tower tube are similar to those employed by Truog, except that the tube is provided with an adapter, *D*, at the top. This adapter has a belled top, which not only affords a tight connection with the rubber stopper, *E*, but can be readily separated from the stopper in disconnecting the several parts of the apparatus. This adapter is connected to the tube, *C*, by means of a packing of pure gum tubing. The stopper, *E*, has two holes, one of which admits the tip of the automatic pipette, *H*, and the other the lower tube of the U-tube,

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[2] Truog, E. Method for the determination of carbon dioxide and a new form of absorption tower adapted to the titrimetric method. Jour. Ind. and Engin. Chem. 7: 1045–1049. 1915.

F. The automatic pipette is connected through a three-way cock to the stock bottle containing the $Ba(OH)_2$ solution and is filled by raising the pressure in the bottle by means of the rubber bulb, *L*, opening the pinch-cock, *2*, and turning the glass cock to the proper position. The pipette is drained by turning the stop-cock over, and a mouth piece, *J*, is provided with an intermediate soda-lime tube, *S*.

One of the arms of the U-tube, *F*, is fused to a cylindrical separatory funnel, *G*, which serves as a container for the water used in diluting the $Ba(OH)_2$ solution and in washing out the tower when the aspiration is completed. This funnel is filled by raising the pressure in the large stock bottle of water with the rubber bulb, *L*, and opening the pinch-cock *3*. The other arm of the U-tube is connected to the intake of the meter, *M*, which in turn is connected to the aspirator. This arrangement makes unnecessary a third hole in the stopper, *E*. The U-tube and automatic pipette are supported by clamps attached to a standard.

TECHNIQUE OF THE DETERMINATION

Clean glass beads are placed in the tower, *C*, to a depth of from 16 to 20 inches, the depth depending upon the quantity of $Ba(OH)_2$ solution to be used. The stopper, *E*, is placed tightly in the adapter, *D*, at the top of the tower, and carbon dioxide-free air is aspirated rapidly through the beads and tower to free them of CO_2. After about five minutes of vigorous aspiration the suction is released, and the automatic pipette is filled to the mark with $Ba(OH)_2$ solution. Should the solution overrun the mark on the pipette stem, on releasing the air pressure by opening pinch-cock, *1*, the solution will run back in the bottle by opening pinch-cock, *2*, and the proper level may be reached in the pipette. The three-way cock of the automatic pipette is then turned over, and the $Ba(OH)_2$ solution allowed to flow into the tower. The last drop is removed by blowing twice through the mouth-piece, *J*. It was found that when blown uniformly, the pipette would deliver with a maximum variation of 0.01 cc. Since 1 cc. of $\frac{N}{4}$ $Ba(OH)_2$ is equivalent to about 6 mgm. of CO_2, 25 cc. will absorb about 125 mgm. of CO_2 and leave a safe excess of $Ba(OH)_2$. Should the quantity of CO_2 to be absorbed exceed this amount, two charges from the pipette must be transferred to the tower; if less, one charge is employed, and about an equal volume of CO_2-free water. The tubulure of the suction flask is then connected to the respiration chamber, a minimum of rubber tubing being exposed to the current of gases. In the bulk-grain respiration studies, an 18 in. calcium chloride tower, *A*, has been employed as a respiration chamber. The latter is connected at the top to a gas washing device charged with 50% KOH solution for remov-

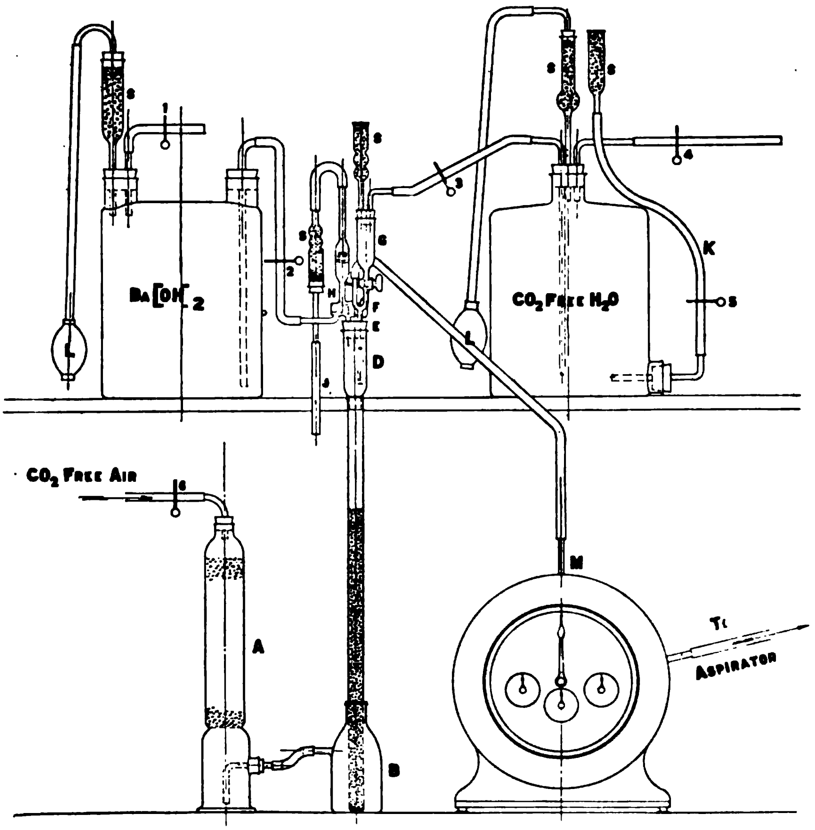

Fig. 1

ing the CO_2 in the air employed for flushing out the air in the chamber. Pinch-cock, *6*, being opened, aspiration is begun at a slow rate, the gases being drawn through the meter, *M*. The meter readings show the volume of air which has been drawn through the system. With bulk grain ten volumes of the capacity of the respiration chamber completely flushes out the CO_2 in the latter. After about one volume of air has been drawn through the tower the rate of aspiration may be increased. It has required about 45 minutes to complete the aspiration in the studies mentioned.

The tower is then disconnected at the stopper, *E*, and elevated from the suction flask sufficiently to permit the beads and $Ba(OH)_2$ solution to flow down into the flask. About 50 cc. of CO_2-free water are run from the separatory funnel, *G*, down the sides of the tower, while the latter is being revolved in such a manner as to insure thorough washing of its inner wall. The suction flask is disconnected from the respiration chamber, the tower lifted out of the flask, and the residual $Ba(OH)_2$ titrated against a standard HCl solution, using phenolphthalein as an indicator. Checks of the apparatus and method, using C. P. $CaCO_3$ have demonstrated their desirability and accuracy for this purpose.

PREPARING THE CARBON DIOXIDE-FREE WATER

The stock-bottle for the CO_2 free water may be easily filled without removing the stopper by disconnecting the rubber tube to which pinch-cock, *3*, is attached, and connecting it to the distilled-water container, opening pinch-cock, *4*, and connecting the tube to which it is attached to the aspirator. When suction is applied by means of the latter, water is rapidly drawn into the bottle. The water may be rendered free from carbon dioxide by closing pinch-cock, *3*, and opening pinch-cock, *5*. Air may thus be passed vigorously through the water, about thirty minutes of aspiration rendering it sufficiently pure for this purpose. To determine its freedom from CO_2, 100 cc. are titrated against $\frac{N}{20}$ KOH, using phenolphthalein as an indicator. It should not require more than 0.2 cc. of the KOH solution to produce a permanent pink coloration.

The apparatus arranged and operated in the manner described seems to satisfy the requirements outlined in the second paragraph. It has been employed in this laboratory with very satisfactory results.

ENVIRONMENT OF SEEDS AND CROP PRODUCTION

BYRON D. HALSTED AND EARLE J. OWEN

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In this paper are given the results of a series of tests carried out for the purpose of determining the effect which might be exerted on germination and early growth by placing seeds in different positions, and also the relative viability and vigor of seeds from different positions in the pod. Seeds of the Scarlet Runner bean were employed in all of the tests because of their large size and favorable flat shape. Only three positions of the seeds were tested, namely (1) laid flat, (2) with the eye up, (3) with the eye down. The depth of planting was uniformly 2 inches below the surface, and special care was taken to have the center of gravity of each seed, however placed, level with the surface of the soil, after which the cover of fine earth was added and the top of the bed brought to a level by means of a straightedge.

There were six plantings in duplicate, making in all 4050 seeds. The varying conditions during the winter made some differences among the six sets of experiments, but all of the seed-positions were treated alike, and are strictly comparable. At the same time a test was made of the relative value for planting of seeds from pods with two, three and four seeds respectively and also of the bearing of the position of the seeds in the pod upon their viability and vigor.

All the tests were made during the period extending from November 21, 1916 to March 12, 1917. No record of the soil temperature was made during the first series, but it was comparable with that for the last one. It is noted that the Scarlet Runner seeds are sensitive to the soil heat, and the viability falls rapidly with the temperature, for example from 92.9% in early December to 76.0% in February (18.1°C.) and arose again to 94.2% in March (21.5°C.)

The seedlings were harvested when they averaged near 300 mm. in length, the periods of growth ranging from twenty-four to thirty days and records for each seedling were made of its weight (that of the original seed being deducted) and of lengths of hypocotyl, first, second and third internodes and total length.

The averages for the time required for the seedling to reach the surface of the soil (emergence) are: flat 12.54 days, eye up 13.02 days and eye down 12.80 days. This shows that seeds placed flat are a full half day quicker in breaking ground than when the eye is placed uppermost.

Table 1 shows the greatest viability for the position with the eye down and least where the seeds are placed with the eye up. The greatest vigor is associated with the flat seeds, but the hypocotyl is longest where the seeds are planted with the eye down.

TABLE 1

Averages for the three positions in the soil for the combined six series

	FLAT	EYE UP	EYE DOWN
Viability	86.12%	81.00%	87.22%
Vigor (green weight)	8.98 gr.	8.78 gr.	8.74 gr.
Hypocotyl	12.54 mm.	11.63 mm.	12.96 mm.
First internode	137.17 mm.	137.6 mm.	136.88 mm.
Second internode	97.43 mm.	93.20 mm.	96.71 mm.
Third internode	46.80 mm.	35.80 mm.	49.56 mm.
Total length	310.11 mm.	292.11 mm.	317.83 mm.

It is noted that the loss of hypocotyl length when the seeds are with eye up, is balanced by the longer first internode, so that the length from root juncture to the second node is practically the same for all three soil positions, but after that point is passed, the seedlings from seeds planted with the eye up fall behind the others. There is little choice between the flat and the eye down position and therefore in field planting the ordinary method seems satisfactory, namely to drop the seeds flat upon the ground.

Weight. Table 2 shows that the seed-weights vary much with the numbers of seeds and with the position of the seeds, in the pod. The seeds averaged lowest in weight in the 2-seeded pods and there was but little difference in the 3-seeded and 4-seeded pods, the former being the heavier. For position in the pod the basal seeds averaged lightest and the middle seeds are the heaviest, those from the middle of 3-seeded pods being heaviest of all.

TABLE 2

Relations of number of seeds and their position in the pod to weight, viability and vigor

TYPE PLANTED	WEIGHT (SEED)	VIABILITY	VIGOR (SEEDLING WEIGHT)
	grams	*per cent*	*grams*
2-seeded, base	0.847	87.30	7.741
2-seeded, tip	0.908	84.18	8.388
3-seeded, base	1.066	81.53	7.329
3-seeded, middle	1.171	87.51	7.960
3-seeded, tip	1.101	75.08	7.593
4-seeded, base	0.997	76.43	7.153
4-seeded, first middle	1.082	83.76	8.038
4-seeded, second middle	1.127	84.40	8.193
4-seeded, tip	1.107	83.73	7.764
Pod averages			
2-seeded	0.928	85.74	9.065
3-seeded	1.115	81.37	7.627
4-seeded	1.078	82.08	7.408
Position averages			
Base	0.970	81.75	7.408
Middle	1.138	84.08	8.038
Tip	1.041	81.00	7.915

Viability. Germination power is greatest in the seeds from 2-seeded pods and there is but little difference between those of the 3-seeded and 4-seeded pods. The seeds borne in the middle have a higher viability than either the basal or tip ends.

Vigor. The seeds from 2-seeded pods produce a greater average weight of seedling than those from 3- and 4-seeded pods. In pod averages with a single slight exception, there is a uniform negative correlation between seed-weight and both viability and vigor.

When considered as to the position in the pod the heaviest seeds show the greatest viability and produce seedlings of greatest vigor, while the lightest seeds (again with a slight exception) show the least viability and vigor.

Observations. The above results indicate that the common practice of dropping the seeds flat upon the soil is satisfactory. The comparatively smaller seeds when borne two in a pod are superior in viability and vigor, and the middle seeds (from 3- and 4-seeded pods) outrank all others in weight.

Both number of seeds and their position in the pod are environmental factors that influence the crop-producing value of the seeds. If the selection of seeds for planting is with pods only, the first choice is those bearing two seeds. If only position in the pod is considered the middle seeds are chosen, but if both pod and position are regarded the tip seeds in two-seeded pods are superior to all others and the second choice is the third seed from the base in 4-seeded pods, followed closely by seeds from the other two middle positions.

The second seed from the base is always of high grade and may be exceeded by the one next above when the pod has four seeds.

BOOKS AND CURRENT LITERATURE

THE MOSSES OF NEW YORK.—Doctor Grout's Moss Flora of New York City and Vicinity [1] is a valuable addition to the list of bryological works now available for moss students in the northeastern and middle Atlantic states: It is an attractive book of 119 pages, containing keys to the families, genera, and species, descriptions of families and genera, and interesting notes on the habitat and distribution of the various species. At the back of the book are 12 plates, containing 20 half-tone illustrations made from some of the excellent photographs for which the author is noted.

The area embraced in the book, or annotated list as it might be called, includes all counties of New York and New Jersey lying adjacent to the city, with localities outside of this area for rare or unusual species. The author notes that he has for fifteen years "made a careful study in the field, of the mosses of eastern Long Island and of Staten Island" and he accordingly includes all available data for Long Island. The area includes the region around Closter, New Jersey, so exhaustively collected over by the late C. F. Austin, whose work is thus referred to by Dr. Grout: "In New Jersey the mosses of the north and those of the south meet, and it seems to one who scans Austin's work with care that he found there almost all the mosses of eastern North America." Dr. Grout's list enumerates about 380 species and varieties, with notes on a few other species, so that its range of usefulness is greater than its title would indicate.

A carefully prepared list such as this will always stimulate study in the locality to which it pertains and, in any of the more densely settled regions it will, to quote again from the author's preface, "put on scientific record facts of natural history that will soon have vanished beyond the possibility of record or recall." We hope to see other regions of our country represented by lists of this character.

Noting the peculiar lack of tree-growing mosses around New York City the author is inclined to believe the cause to be gases produced in the city. The reviewer is inclined to believe that, around industrial cities at least, iron-ore dust, coal dust, etc., with associated products such as sulphurous and sulphuric acids, may be of importance in preventing the appearance of small-spored plants such as mosses, lichens, liverworts, and parasitic fungi on fences, tree trunks, leaves and other situations.—O. E. JENNINGS.

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[1] Grout, A. J. The Moss Flora of New York City and Vicinity. Pp. 119, pls. 12. Published by the Author, New Dorp, N. Y., October 1916.

GROWTH-FORMS OF NATAL PLANTS.—Bews has added another paper to the valuable series in which he has so materially increased our knowledge of the ecological aspects of Natal.[1] This contribution discusses the growth-forms exhibited in the 3034 species which form the flora of Natal. The system of Raunkiär is used, with its most recent modifications, comprising the recognition of stem-succulents and epiphytes and the subdivision of the large erect and woody plants, or phanerophytes, into three classes on the basis of their height. The author is by no means blind to the artificial character of the Raunkiär system of growth-forms, and expresses his preference for the more natural system of Warming. The simplicity of the former, however, and the difficulty of applying even the least exacting system to the plants of a region which is ecologically so little known, have led him to use this popular system of analyzing the ecological character of the flora. Natal is poor in large trees and in stem-succulents and epiphytes. Large shrubs and small trees (microphanerophytes) and small shrubs (nanophanerophytes) each form 14% of the flora. Root-perennials and other low perennials (chamaephytes) form 19% of the flora, while the true root-perennials (hemicryptophytes) and the bulbous and tuberous plants (geophytes) each form 18%. When compared with the average conditions for the world (the normal "spectrum"), Natal is shown to be rich in chamaephytes and geophytes and relatively poor in hemicryptophytes and therophytes (annuals). Bews discusses fully the rôle of the various growth-forms in the forests, bush, and veld of Natal.—FORREST SHREVE.

WORKING PLANS FOR FOREST ORGANIZATION.—The original edition of Recknagel's Theory and Practice of Working Plans, which appeared in 1913 has recently been revised and corrected.[2] As the title implies, the book concerns itself with the practice rather than the scientific side of forestry. It deals with that branch of forest practice known as Forest Organization. Quoting from the introduction: "Forest organization, a subdivision of forest management, deals with the principles of organizing a forest for business." The book is intended for professional foresters and students of forestry; it is too technical for the layman who merely desires a general view of the subject. As a text book it has already gained wide popularity in forest schools.

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[1] Bews, J. W. The Growth-Forms of Natal Plants. Trans. Royal Soc. So. Africa, 5: 605–636. June, 1916.

[2] Recknagel, A. B. The Theory and Practice of Working Plans. New York, John Wiley and Sons, 1917.

As stated in the preface to the first edition, the author makes no claim for presenting original theories, but aims merely to present the best of European ideas adapted to the needs of American forestry. European text books, while serving as a foundation for American forestry, have often failed to meet the needs of the student and practitioner in this country, because European conditions are very different from those met here. The endeavor of the author has therefore been to present the most fundamental principles and to show how they may be applied under American conditions. Numerous references to American forest problems bring the ideas home to the American reader in a way which the older European literature can not do.—G. A. PEARSON.

THE NODE OF ANGIOSPERMS.—The first member of a series of papers by Sinnott and Bailey on the phylogeny of the angiosperms proposes a principle[1] which may prove to be of broad application in classification. Study of a large number of angiosperms shows that while the petiole is too much influenced by ecological factors to furnish facts of phylogenetic significance, the basal region of the leaf shows a simpler and more constant condition, and in it the number of leaf-traces is characteristic of the great groups. It is concluded that among angiosperms the primitive number of traces is three (as in Amentiferae), and that evolution has taken place in two directions: (1) by increase in the number of leaf-traces, as in Umbelliflorae, (2) by reduction to one trace as a consequence of fusion of the original three (Cruciferae), or of disappearance of the two lateral strands (Aquifoliaceae). In another paper of the series[2] the theory is extended to account for the position and distribution of stipules. In the third paper of the series[3] the origin of herbaceous angiosperms from woody forms is discussed at length, from the standpoints of paleobotany, anatomy, phylogeny and phytogeography. It will be seen that the good old story of transition from herbaceous to woody stem structure has received some hard blows of late years.—M. A. CHRYSLER.

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[1] Sinnott, E. W. The Anatomy of the Node as an Aid in the Classification of Angiosperms. Amer Jour. Bot. **1**: 303–322. 1914.

[2] Sinnott, E. W. and Bailey, I. W., Nodal Anatomy and the Morphology of Stipules. Amer. Jour. Bot. **1**: 441–453. 1914.

[3] Sinnott, E. W. and Bailey, I. W. The Origin and Dispersal of Herbaceous Angiosperms. Ann. Bot. **28**: 547–600, pls. 39, 40. 1914.

NOTES AND COMMENT

The Plant World is now in its twentieth year. It began its career as a magazine for the amateur botanist and nature-lover. The number of amateurs interested in botany twenty years ago was not as great as the number of men and women who are today professionally engaged in botanical work or the application of scientific principles to problems of plant utilization or plant production. When The Plant World was founded the professional botanists of this country were outnumbered by hundreds of persons who derived pleasure and benefit from the collecting of plants or the use of the microscope. At the present time the men who are engaged in research or instruction in pure botany, and the men who are deriving enjoyment from botanical pursuits as a hobby, are even more heavily outnumbered by the thousands who are using their knowledge of plants in the service of mankind.

The changes that have been made in The Plant World during the twenty years of its existence have been a reflection of the changes in botany and its allied subjects, and have been a part of the growth of science. It occupies a unique place among botanical journals in having no financial support from any institution or society, deriving its income entirely from subscriptions and from sources of profit which are bestowed upon it by members of the Plant World Association. This makes its policies more independent and its field of service more capable of rapid adjustment to the changes of the times.

We are now passing through a period of our national history in which it seems particularly fitting that we should consider the functions which are being performed by our scientific journals, and the rôle that they can play in the relation of science to the general progress of human affairs. The sums of money expended in the publication of scientific work are largely a direct tax upon science itself, being derived either from the emoluments of individual scientists, or from funds which are just as available for promoting investigation as for publishing results.

It is the earnest desire of the members of the Plant World Association that this journal use its resources in a very clear-cut sense of service to botany in particular and to science in general. Like the majority of botanical and zoological publications The Plant World is not in the custom of paying for its contributions, and is therefore in the position of offering to its readers that which its contributors have regarded as worthy of their time and efforts. Practically all of the papers published in The Plant World during the past five years have been contributed by readers of the journal. It is to this group, therefore, that we must look for all efforts to increase the effectiveness of our pages at the present time. We are deeply desirous that this journal should serve not only as a record of investigations but as a means of articulating the botanical work of America with the progress of science in general and with the appreciation of the growing audience outside of strictly professional circles to whom the larger features of our advancement are of interest and value.

The Plant World is anxious to have its readers make still further use of its pages as a medium of publication. Articles embodying original work are always of the highest order of importance, but it is desirable that such articles be succinct, even if they are not brief, both for the sake of the economy which is now (and always) a national duty, and for the sake of securing a larger audience among the hurried readers who also see many other periodicals. The time is rapidly approaching—if it is not already here—when the funds which are available for scientific work in America will be measured directly by the degree to which the intelligent people of our country understand the progress and problems of science. It is the manifest duty of the men who are engaged in scientific investigation to keep in view the utility of their work, which may be of an immediately practical character or may be of an indirectly practical but much more fundamental character. It is equally the duty of every worker in natural science to prepare from time to time short articles regarding his special field of work, written without undue use of technical terms and in a style which is readable without being superficially popular. The Plant World is not only willing to publish articles of this character but is anxious to secure them. The existence of a journal containing matter of this sort, covering botany and its allied fields, will be welcomed by the rapidly growing body of men and women who know something of the methods and aims of modern science but have no means of keeping in touch with its rapid and diversified progress. Without some medium by which the achievements and hopes of the investigator can be made known to the educated public of the country, our scientific work will find itself dissipated over a field of small and immediate practicalities, with its fundamental problems and important aims known only to a small group of highly trained investigators, who will find themselves isolated by the lack of being understood and hampered by the failure of securing financial support for their work. It is not an easy matter for the specialist to prepare articles of this character, but it is his duty to do so. There is no group of men in America who are better qualified to perform such a service for botany than are the readers of this journal, and it is hoped that some of the splendid support which has filled its pages in past years will be given it in future along the new lines indicated as well as along the familiar ones.

After this journal was taken over by The Plant World Association in 1907 it depended for its financial support entirely on the income from subscriptions and advertising, and on the personal efforts of the members of the Association. During those years the journal was run with a small annual deficit, which was met by members of the Association, to whom interest-bearing notes were issued. During this period the size of the journal was maintained at a definite number of pages and the most economical arrangements were made for printing.

In order to provide an endowment for The Plant World, one of the members of the Association turned over to the journal the sale of apparatus which he had devised in the course of his scientific work, thereby making this apparatus generally available. Other members of the Association have since turned over special apparatus or publications to The Plant World. The income derived from these sales has served to meet the deficit during the last two years, although it has been necessary to issue additional notes in order to secure a working capital for the maintenance of a stock of the items sold. The steadily increasing cost of printing and of illustrating has made very necessary the additional income secured. The absence of an annual deficit, however, together with the loyal support which has been unfailingly given the Managing Editor by the members of the Association, has made it possible to issue a greater number of pages per annum and a larger amount of illustration than would have been possible otherwise. The generosity of our contributors has also been manifested on numerous occasions in connection with the regrettable but necessary ruling that articles more than 15 pages in length and illustrations in excess of four must be paid for at cost. The journal is now in the position of being assured of an income sufficient to publish its customary number of pages. The profits from the sale of apparatus have to be applied to the replenishment of stock, to the taking up of notes, and to the maintenance of a safe reserve, over and above which they are devoted solely to making the journal larger than it would otherwise be.

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THE INTERPRETATION AND APPLICATION OF CERTAIN TERMS AND CONCEPTS IN THE ECOLOGICAL CLASSIFICATION OF PLANT COMMUNITIES[1]

GEORGE E. NICHOLS

The Sheffield Scientific School of Yale University, New Haven, Connecticut

During the past seven years much of the writer's study has been along the line of local physiographic plant ecology, and the need has constantly been felt of some logical and adequate, yet at the same time simple and to a certain extent elastic scheme which could be readily adapted to the ecological classification of the vegetation of any region. The groundwork for such a classification is afforded by the principle of succession, the fundamental bearing of which on the relationship and evolution of plant communities has been indisputably established by the work of Cowles (7, 8, 9, 11), Whitford (24), Clements (3, 4), Moss (16, 17) and others. The principal object of the present paper is to outline a plan of classification which it is thought will recommend itself because of its lack of complexity and because of the readiness with which it can be applied, and in this connection to express the writer's views regarding the interpretation and application of certain ecological terms and concepts. Incidentally, several new terms, or rather combinations of terms already in use, are introduced, which it is thought will prove serviceable by very reason of their simplicity of interpretation and application. The scheme of classification itself is by no means wholly new or original. It is the outgrowth, and perhaps not a very radical modification, of the classification originally devised by Cowles (8).

THE UNIT OF VEGETATION WITH REFERENCE TO HABITAT

The association. From the standpoint of physiographic ecology (synecology) the association, in the last analysis, repre-

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[1] Contribution from the Osborn Botanical Laboratory.

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sents the fundamental unit of vegetation. The association may be defined as: any group or community of plants, taken in its entirety, which occupies a common *habitat* (see Cowles 6, p. 939). In terms of dynamic plant geography it may be further defined as: any stage in a given successional series.

Uniformity of habitat, then, affords the criterion of the association. The word habitat commonly has been applied somewhat loosely, but from an ecological standpoint it is desirable that it should be delimited as precisely as possible. As conceived by the writer, the habitat may be defined as: any unit area in which the combined influence of the various external factors which determine the ecological aspect of the vegetation is such as to produce an essentially uniform *environment.* It is the environment which determines the ecological aspect of a plant community. The nature of the environment, in turn, is determined by a complex of physical and chemical factors which, in a general way, may be classified as (1) climatic, (2) edaphic, and (3) biotic. (1) The *climatic factors* comprise all those atmospheric conditions through whose widespread uniformity the character of the regional climate is determined. These include: (a) atmospheric humidity, (b) precipitation, (c) temperature, and (d) light. (2) The *edaphic factors* include all conditions which are attributable, directly or indirectly, to soil or topographic agencies. Their influences may be exerted either through the medium of the ground or through that of the atmosphere. The ground influences are attributable to: (a) soil factors (the physico-chemical nature of the soil, and the ground-water relations); (b) slope factors (the inclination of the ground's surface, i.e., the degree to which it departs from the level); and (c) dynamic physiographic agencies, where these are operative (as seen in the phenomena of erosion and deposition). The edaphic atmospheric influences are seen in the local modification of the climate associated with differences in exposure, which in turn are attributable to variations in topography: thus, a north-facing slope commonly possesses a somewhat different "local climate" from a south-facing slope; similarly, the "local climate" of a ravine differs from that of an exposed hillside; etc. While such local atmospheric dissimilarities represent merely modifications of the climate of the region, a distinction may well be drawn between these *local climatic factors*, which in the main are attributable to edaphic influences, and the *regional climatic factors*. For the sake of convenience, any area in which the combined influence of the various edaphic factors is essentially uniform throughout may be termed an *edaphic unit area*. (3) The *biotic factors* include all conditions which, directly or indirectly, are attributable to plant or animal agencies. Their influence is seen (a) in the ameliorating effect of humus on the water relations, etc. of the soil, and (b) in the effect of shade, as it inhibits the development of intolerant plants, modifies the evaporating power of the air, etc. (in this connection, see Cowles, 11).

In view of the foregoing remarks, the habitat may be further defined as any unit area in which the combined influence of climatic, edaphic, and biotic factors is essentially uniform throughout. Giving the term this precise interpretation, it becomes evident at once that many an area, such as a pond, a ravine, or a salt marsh, which only too frequently is characterized as a "habitat," should be regarded rather as a series of habitats. The various factors which, as above indicated, are responsible for the local variations in the nature of the environment and for the consequent delimitation of distinct habitats, in other words, the edaphic and the biotic factors, taken collectively, may be termed the *habitat factors*, in contrast to the *regional climatic factors*, the influence of which is widespread and essentially uniform throughout the region.

Although the nature of the habitat affords the actual criterion, plant associations, as a rule are most readily distinguished in terms of their vegetation; thus, in the case of a pond: the *Nymphaea* association, the *Scirpus-Typha* association, etc.

Floristic subdivisions of the association. In its ecological aspect an association is essentially homogeneous throughout. Floristically, however, it is commonly subject to more or less variation. Where the variation concerns the dominant species (*facies*) it is often possible to distinguish different *consociations*, i.e., subdivisions of the association "characterized by a single dominant" (Clements 4, p. 129). Where the variation concerns species of secondary importance it is similarly possible to distinguish different *societies*. Thus, a deciduous forest may be essentially uniform in its structure throughout, so far as the dominant species are concerned; or certain species may dominate locally, giving rise to more or less distinct consociations. Similarly, the herbaceous or shrubby vegetation in such a forest may, and usually does, vary locally, giving rise to more or less distinct societies. In the case of both the consociation and the society, the floristic composition of the vegetation affords the sole criterion, although there may also be slight but relatively inconsequential variations in the habitat. The consociation and the society, then, represent floristic and not ecological units.

The association-type. The nature of any given habitat is determined by a number of more or less definite, though not always tangible factors. Wherever, within a given climatic region, a given set of habitat factors is duplicated, the same type of habitat is the result. To express it algebraically: if it is assumed that the nature of a given habitat, H_1, is determined by the combined influence of the factors, A_1, B_1, C_1, and D_1, and if this fact be expressed by the equation $H_1 = f(A_1, B_1, C_1, D_1)$, then wherever the combination of factors A_1, B_1, C_1, D_1 recurs, the value of H will be the same. Of course, the exact application in practice of this criterion of the habitat would necessitate a vastly more accurate knowledge of the factors which determine its nature than is actually available, so that as a matter of fact the parallels must be based to a large extent on superficial observations. But, in a general way, numerous parallel series of habitats may be distinguished in every region. In comparing two neighboring ponds, for example, the habitat occupied by the *Nymphaea* association in the one may duplicate the habitat occupied by the *Nymphaea* association in the other; or the habitat of the *Scirpus* association in the one may duplicate the habitat of the *Typha* association in the other; etc. Similarly, the individual habitats occupied in different Connecticut salt marshes by the *Spartina glabra* association are essentially similar throughout; and so on. Habitats which thus are equivalent to one another may be referred to a common *habitat-type.*

In any given region, owing largely to the existence of these parallel series of habitats, there have been developed correspondingly numerous parallel series of associations. Different individual associations which are correlated with the same type of habitat and which as a result agree with one another in their ecological aspect, i.e., which are ecologically equivalent, even though they may differ in their floristic composition, may be considered as belonging to a common association-type. Thus, the *Nymphaea* association in one pond is obviously the ecological homologue of the *Nymphaea* association in a neighboring pond, while the *Scirpus* association in the one may similarly correspond to the *Typha* association in the other. In the same way, an oak forest association in one locality may represent the equivalent, from an ecological standpoint, of a hickory forest association in another locality; and so on. It will be seen that, unlike the association, the association-type is a more or less abstract conception. It may be simply defined as: a type of plant association which is correlated with a given type of habitat. The term association-type has already been used by Schröter (20) in a sense analogous to that here proposed.

The exact delimitation of association-types of course presents many difficulties, but in a general way it is possible to group the innumerable individual associations of a region into a comparatively small number of association-types. To a limited degree it is possible to refer to these association-types in terms of the habitat (or of the edaphic unit area) thus: rock face association-type,—middle beach association-type. But such a method of nomenclature, while desirable in theory, has its limitations in practice, owing in part to the difficulty of finding expressions which even in a general way are descriptive of the habitats concerned (especially when biotic factors are taken into account) in part to the deficiency of our knowledge concerning the habitat factors. It is therefore usually necessary, just as in naming the associations, to resort to the vegetation for titles; thus:

submersed aquatics association-type, water lily association-type, oak-hickory association-type, etc.

It should perhaps be added that the conception of the habitat-type and of the association-type need not necessarily be confined to any given climatic region. This is exemplified particularly well by the association-types of salt marshes, which in temperate regions are essentially uniform in their ecological aspect under various climatic conditions. In general it can be stated, from the standpoint of dynamic plant geography, that in comparing the association-types in regions having different types of climate, the highest degree of parallelism is exhibited between the more primitive (i.e., the more xerophytic or more hydrophytic) association-types; and that, conversely, the least parallelism is exhibited between the more ultimate (i.e., the more mesophytic) association-types. In comparing association-types in regions having similar types of climate, on the other hand, the parallelism also extends to these more ultimate association-types.

THE SUCCESSIONAL RELATIONS OF PLANT ASSOCIATIONS

Geologic versus contemporaneous successions. Cowles (11) has defined three types of succession: regional successions, which are attributable to widespread climatic changes; topographic successions, which are associated with changes in topography resulting from erosion and deposition; and biotic successions, which are due to plant and animal agencies. Regional successions, on the one hand, extend over long periods of time; biotic successions, on the other, take place with comparative rapidity. According to Cowles, "If, in their operation, regional agencies are matters of eons, and topographic agencies matters of centuries, biotic agencies may be expressed in terms of decades. . . . So rapid is the action of the biotic factors that not only the climate, but even the topography may be regarded as static over large areas for a considerable length of time" (11, p. 172). Now it is of course true that along actively eroding and depositing streams and coasts topographic agencies may operate with sufficient rapidity as to institute marked changes within a comparatively short period of time: along streams such rapid changes are commonly associated with the erosion of ravines in uncompacted rock and the building up and destruction of flood plains; along the coast they are associated with the erosion of bluffs in uncompacted rock, and the development or destruction of coastal swamps (e.g., salt marshes), beaches and sand dunes. In this connection, see especially Cowles (7, 8). But, in the large, rapid changes such as these are the exception rather than the rule. Over much the greater part of the earth's surface the changes due to topographic agencies are consummated so slowly that their influence on the vegetation, like that of climate, becomes apparent only when geologic periods of time are taken into account. It is indeed open to question whether in the main the successions due to topographic agencies do actually take place more rapidly than those due to changes in climate. In the glaciated regions of the eastern United States, for example, the land surface for the most part has undergone little alteration since the recession of the continental ice sheet; yet during this period it is generally agreed that there have ensued profound climatic changes, which have been accompanied by correspondingly great transformations in the character of the vegetation (in this connection, see Nichols 18, pp. 237, 245, 249).

If account is taken of the three types of succession defined by Cowles, then it is evident at once that vegetation can never attain a condition of equilibrium. As Cowles (8, p. 81) aptly phrases it, "we have a variable approaching a variable rather than a constant." While conceding, however, the far-reaching importance of the climatic and topographic changes which have ensued and which will continue to ensue in geologic time, it seems to the writer that, in attempting to solve the relatively contemporaneous problems of dynamic plant geography, much more is to be gained than lost by postulating the climatic conditions of the present, and by ignoring topographic changes, except in so far as these manifestly proceed with sufficient rapidity as to become effective within the present climatic era.

Permanent and temporary associations. Postulating thus the continuance of a relatively uniform climate, from the standpoint of dynamic plant geography two secular classes of plant associations are distinguishable: permanent and temporary. A permanent association is one which has reached a condition of equilibrium with respect to climatic factors, on the one hand, and habitat factors, on the other. It has attained the highest degree of mesophytism which the nature of its environment will permit. It represents the culminating member of a specific successional series. A temporary association, on the other hand, is one which has not reached such a condition of equilibrium. Through the influence of various habitat factors it is destined to become superseded sooner or later by a (usually) more mesophytic type of vegetation. It therefore represents merely a transient stage in a given successional series.

The concept of a uniform regional climax association-type. Under favorable conditions, as a consequence of the progressive reaction of the habitat factors and the concomitant succession of plant associations, the vegetation of a given area may attain the highest degree of mesophytism which the climate of the region permits. This type of association, which represents the climax for the region, may be designated the regional climax association-type.[2] Now it is commonly stated or implied in ecological literature that in every region, as the logical consummation of progressive successional changes, the vegetation of all soils and all types of topography is destined eventually to acquire the same degree of mesophytism that characterizes the regional climax association-type; that, while in unfavorable situations the influence of certain habitat factors may diminish the rapidity of the succession, it does not alter the final outcome; that ultimately, although the time may be indefinitely postponed, the regional climax is destined to be attained in all areas. If this idea is correct, then of course no associations can be regarded as permanent except those which belong to the regional climax association-type. This is the working-hypothesis which the writer followed in his earlier field-studies; but observations continued over a number of years have made it seem increasingly evident that such an assumption is untenable from the standpoint of contemporaneous dynamic plant geography. This hypothesis fails either to accord with theoretical considerations or to harmonize with observed facts.

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[2] Clements (4, p. 128) would restrict the use of the term association to these climax associations.

Edaphic influences as limiting factors in succession. Now of course it is not disputed that the trend of succession is almost universally mesotropic; that in the vast majority of areas where the phenomenon of succession is taking place there is a constant tendency for the vegetation to approach in its ecological aspect that which characterizes the regional climax association-type. However, it is certainly true that the rate of succession is influenced to a marked degree by the edaphic factors; and, in the opinion of the writer, the effect of these factors goes even further: not only do they influence the rate of succession; they also determine the extent to which the succession can proceed. In other words, they place a limit on the degree of mesophytism which is capable of attainment. The point which it is desired to emphasize is simply this: that while in edaphically favorable situations the regional climax association-type is capable of attainment, in edaphically unfavorable situations the succession may become arrested at a point far short of this climax; and that in this way there may arise associations which, while they are less mesophytic than the regional climax association-type, nevertheless are permanent with reference to the coeval climatic conditions and must therefore be regarded as climax-types.

This point is capable of logical demonstration, somewhat as follows. In the first place, it may be stated that the ecological aspect of any plant association is the combined function[3] of those factors which determine the environment; in other words, the aspect of the vegetation is conditioned by the combined influence of the climatic and the habitat factors. Assuming, then, the climate to be a regional constant, it follows that the ecological aspect of an association is the direct combined function of the habitat factors. Carrying the process a step further, it seems obvious that, with certain exceptions like those noted in a preceding paragraph, all of the habitat factors are relatively constant except those which are due to plant and animal agencies. It would follow, therefore, that the ecological aspect of an association is the direct combined function of these biotic factors alone. Now, with these deductions in mind, it might perhaps be expected to follow that through the gradual amelioration of the habitat, brought about by the progressive reaction of the biotic factors, the culminating member of every successional series throughout a given climatic region would be the same, the only difference between them being in point of the time when this ultimate condition is reached. But in this connection must be taken into account Liebig's *Law of the Minimum,* which states in effect that: if any reaction or process is the combined function of several factors (or variables), the extent to which the reaction or process may be carried is limited by the effect of that factor which possesses a minimum value, or which is present in relatively minimal amount. The application of this law to ecological problems has already been suggested by Adams (1) and Hooker (15); and herein lies the explanation of what the writer proposes to term the *edaphic climax association.*

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[3] It would be perhaps more accurate to state that the ecological aspect of a plant association is a function of each of the integral factors which in combination determine the nature of the environment. It is thus a function of temperature, a function of light, etc.

The edaphic climax association. Disregarding for the moment the influence of biotic factors, it may be stated, on the basis of Liebig's Law, that in every habitat the degree of mesophytism which it is possible for the vegetation to attain is conditioned by the limiting edaphic factor. Where all the necessary edaphic factors are sufficiently represented, the highest degree of mesophytism permitted by the climate is capable of attainment. But the limiting influence of any one factor may prevent succession from proceeding beyond a certain stage.

The exact limiting factors of course vary with the habitat and are not easy of analysis, except in a very superficial way. A few illustrations, however, may be suggestive. In the case of a precipitous cliff, in a very general sense, the steepness of the slope may be regarded as the limiting factor. Along a bleak, exposed seacoast, wind, or perhaps better the absence of quiet air, may similarly represent the limiting factor. Most commonly, unavailability of sufficient water, to whatever causes this may be due, is the direct limiting factor.

In a measure, of course, the favorable influence of certain habitat factors, may compensate (or integrate) the limiting effect exerted by others. On precipitous slopes in rock ravines, for example, the factor "water runs off quickly" may be offset to such an extent by the factor "atmospheric humidity is great" that a mesophytic bryophyte flora is able to establish itself; but the factor "no foothold for roots," which may be the chief obstacle to the development of a forest cover here, cannot be wholly compensated by any other factor. Most important of all habitat factors in their compensating influence are those due to plant and animal agencies, particularly humus accumulation and shade as they affect the water relations of the habitat (see Cowles, 11). The significance of these factors in relation to succession is universally recognized, and in some cases their compensating influence is sufficient to completely offset the effect of the limiting factor: in other words, through the cumulative effect of biotic factors the habitat may become so modified that it becomes possible for the climax association-type of the region to develop. But elsewhere, in varying degree, the influence of the limiting factor is too pronounced to be completely overcome, and succession becomes permanently arrested at a stage less mesophytic than the regional climax. In the case of a swamp which has originated through the filling in of a lake by vegetable débris, for example, it is quite conceivable that, as a result of the gradual upbuilding of the substratum through the accumulation of humus, the habitat might eventually come to approximate that of uplands. But here again a limiting factor, which might be designated "decomposition of humus when exposed to air," ordinarily prevents the upbuilding process from proceeding beyond a certain point. It should be added, although it is perhaps quite obvious, that the effect of certain edaphic limiting factors is in turn modified by climatic factors. In a *Sphagnum* bog, for example, the *Sphagnum* tends to grow upward above the original water level, and in cool humid regions like coastal New Brunswick and Nova Scotia (see Ganong, 12) raised bogs may thus be developed; but in less humid regions the evaporating power of the air represents a limiting factor which, in varying degree, inhibits this upward growth of the moss.

The fact seems clear, then, as has already been suggested, that the climax of a successional series in any edaphic unit area is controlled largely by the influence of some limiting factor, and it therefore follows that the nature of the climax association may vary with the nature of the soil or of the topography. The term edaphic climax association may be defined as: the most mesophytic association which is capable of development in any given edaphic unit area through the progressive reaction of the various habitat factors. In a favorable situation, the habitat climax association coincides with the regional climax association-type.

The term edaphic climax association may be used either (1) in point of time, with reference to a specific successional series, i.e., with reference to the series of associations which follow one another in a given edaphic unit area; or, (2) in point of spatial relations, with reference to the group of associations which comprise an *association-complex* (see the following section), where these are genetically related. Used in the latter sense, it suggests the successional relationship which exists between the various associations of the complex. One can refer to such edaphic climax associations as these in terms of the physiographic unit area concerned: thus, trap cliff climax, rock ravine climax, bog climax, salt marsh climax.

One of the most forcible illustrations of the edaphic climax concept with which the writer is familiar is afforded by the New Jersey pine-barrens (see Taylor, 23; Harshberger, 14). This well-known phytogeographic area is situated in the midst of a region whose climate is capable of supporting a highly mesophytic forest. The portion of the coastal plain which it occupies has been uninterruptedly out of water and presumably covered with vegetation since upper Miocene times; yet in spite of this fact, today it is still occupied by a series of associations which, while they represent "an old and climax condition, ancestrally infinitely more ancient than anything in the surrounding area" (23, p. 242), nevertheless, with reference to the climax association-type of the region, must be classed as primitive. It is significant that this particular series of edaphic climax associations has apparently maintained itself in spite of changes in climate. A stronger argument in favor of the potency of edaphic factors in limiting succession could hardly be conceived.

A similar noteworthy example of a widespread edaphic climax is seen in the natural prairie of western Long Island (see Harper, 13). Although, like the pine-barrens, situated in a region of deciduous forests, this area, some 50 square miles in extent, at least during the present climatic era apparently has never become forested, and there is no reason to believe that under the present climatic conditions, even if left undisturbed, it would undergo any appreciable changes in the future.

The association complex. Sometimes the nature of the habitat is essentially uniform throughout a given area, but more often, within an area which from a physiographic or some other standpoint it is desirable to treat as a unit, several different habitats are represented. Thus, for example, in the case of a pond, very largely as the result of differences in the depth of the water, there are numerous distinct types of habitat. Similarly, a salt marsh, a flood plain, a ravine, a rock hill, a sand plain, or a burned area may include a series of habitats which it is desirable to treat collectively. Any such series of habitats may be designated collectively as a *habitat-complex*. The term may be defined as: a group or series of habitats which occupy a unit area and are alike with reference to one or more habitat factors.

The conception of the habitat-complex, like that of the habitat-type is capable of algebraic expression. In the case of a pond, for example, let it be roughly assumed that P = pond, an area which it is desired to treat as a unit. Let A = the habitat factor "ground permanently covered by water;" and, for the sake of simplicity, let B = the habitat factor "depth of water." Then, according as B varies, $P = A(B)_1 + A(B)_2 + A(B)_3$, etc. In other words, all the habitats of the area P are alike with reference to the habitat factor A, and the series of habitats thus embraced may therefore be regarded as constituting a habitat-complex with reference to this factor. As another illustration, let it be assumed that B = an area which has been burned over; let F = the factor "fire;" and let H = the factor "humus destruction." Then, according as H varies, $B = F(H)_1 + F H_2 + F(H)_3$, etc. The area B may thus be regarded as a habitat-complex with reference to the habitat factor F.

Intimately associated with the habitat-complex is the association-complex. The relation between the two is analogous to that between the habitat-type and the association-type. In a pond, for example, correlated with the various individual habitats which comprise the habitat-complex, is a corresponding series of associations: the association of submersed aquatics, the *Nymphaea* association, the *Scirpus-Typha* association, etc. Similarly, in a salt marsh, there may be as many different associations as there are habitats. And just as the habitats in such unit areas, taken collectively, may be referred to as a habitat-complex, so the group of associations which occupies the habitat-complex may be designated as an association-complex. An association-complex may therefore be defined as: a group or series of associations which occupies, and forms a unit with respect to, a habitat-complex. The various ways in which the term association-complex can be applied need hardly be suggested. The associations of any area, taken collectively, may be so designated. The concept finds its most significant application, however, in relation to the *edaphic formation* which will be discussed in the following section.

The association-complex may be referred to in terms of the habitat-complex concerned; thus: pond association-complex (or simply pond complex), salt marsh association-complex, flood plain association-complex, burn association-complex, etc.

The classification of associations. In classifying plant associations, they should first of all be grouped with reference to the developmental relations of the habitats concerned; in other words, with reference to the successional relations of the associations themselves The further classification of the association-complexes thus defined is discussed in subsequent paragraphs.

(*To be continued.*)

RELATION OF THE RATE OF ROOT GROWTH IN SEEDLINGS OF PROSOPIS VELUTINA TO THE TEMPERATURE OF THE SOIL

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SUMMARY

This paper is a summary of numerous observations, a portion only of which are presented, on the growth of the roots of mesquite in soil, and is one of a series on the physiological-ecological relations of roots. The leading results can be given in brief as follows:

The range of temperature of the soil at which root growth in seedlings of the mesquite will take place ranges from about 12°C., as the minimum, to about 42°C., as the maximum.

The most rapid root growth observed in any experiment was of a root with an initial length of 16 mm. which in a period of 12 hours grew 51 mm. The temperature of the soil was 32.5° to 34°C., and the temperature of the air was 22.5° to 23.5°C.

In roots about 50 mm. long, or less, at constant soil temperatures, the rate of growth may gradually increase during a period of 48 hours, more or less.

In roots about 50 mm. or more in length, the rate of growth either remains approximately constant with the passage of time up to 76 hours, more or less, or the rate gradually decreases.

In roots about 50 mm. in length there may or may not be an acceleration of the growth rate during the first 3 to 6 hours of the experiment. In the longer roots this is usually wanting, but in the shorter roots it frequently occurs.

Three types of growth rate variation are to be distinguished, namely, the gradual increase or decrease, as above noted, and which is associated with the length of the root, and major and minor variations. The latter are independent of the age of the

root, but are present in all growth curves which cover a sufficient length of time.

The rate of growth in any individual growing in soil and under constant conditions of soil and air temperature and of illumination, may vary in one and the same experiment from 100% to about 300%. And the extreme range in rate variation between different individuals growing under the same conditions may be much greater than this.

The greatest variation in the rate of growth was observed in roots which were 50 mm., or less in length. Although the length of the root at the time of the "grand period" of growth was not especially studied, the "grand period" appeared to occur when the root was about 50 mm. in length. The behavior of the root as regards the growth rate, therefore, and as regards the variation of whatever kind in the rate, is probably to be associated with the relation of the time of observation to the root's development or more specifically to the "grand period" of growth.

METHODS

The salient features of the method followed in the experiments, and in the procedure, may be briefly presented. Seedlings only were used. Quick germination was secured by filing a slot in the outer seed coats to admit water more readily. After lying a few hours in water the seeds were transferred to glass tubes, 1.7 by 44 cm. in size, which contained sifted sand. The soil was kept continuously moist by frequent watering with tap water, or in some cases Knop's solution was substituted. However, it was learned that for the short time the experiments ran, the roots grew equally well in either the solution or the tap water, so that for the most part water only was used. The tubes were kept in a thermostat, arranged so that the shoots projected from it, and the soil did not usually vary more than 0.5°C. during the course of any experiment. In some instances the chamber in which the thermostats were situated was provided with a means of controlling the temperature independently of that of the thermostat. In others the shoots were exposed to the diurnal temperature changes of the air about them. Since the soil temperature exercised a predominating influence in control of the rate of root growth, as appeared repeatedly, no especial attention was paid to the air temperature, except to record it. However, it may be said that most of the experiments were conducted in a chamber where the air temperature varied less than 2°C. during any experiment. Usually no attempt was made to control the illumination, although at the Coastal Laboratory constant illumination was secured by the use of a 100-watt nitrogen electric lamp placed approximately 2 meters from the thermostats.

In the experiments all of the seedlings were used, and none were discarded because they were "abnormal." Therefore, the maximum range of variation in rate of growth was secured. One of the results obtained was a surprising effect on the vigor of the seedling caused by varying the depth of earth which was used to cover the seeds, suggesting in this fact a prolific cause for failure to survive in nature. To quite do away with this as a possible cause for variation in development seemed rather difficult, although uniformity in planting was attempted. As an instance of the effects of deep planting on the vigor of the seedlings a single experiment will be cited. Five seeds were covered with 30 mm. of moist sand, and five seeds were barely covered with the sand. Cotton plugs were used to prevent excessive evaporation. Both cultures were treated in an otherwise similar manner. At the end of about two weeks it was found that the roots of the seedlings from the lightly covered seeds were from 83 to 153 mm. long, while the roots of those which developed from the seeds that had been covered deeply measured between 44 and 75 mm. in length, with one that was only 5 mm. long. Although there was thus a great difference in the development of the two groups of seedlings, there was nevertheless marked variation in the rate of growth in each group, and this variation occurred in such a manner as to lead to the conclusion that its cause lay in difference of whatever nature in the plants themselves.

RATE OF GROWTH

Preliminary experiments on the relation between the rate of root growth in the mesquite and the temperature of the soil indicated that the roots of the species respond to a relatively large temperature range. Root growth, although slow, does however occur at a soil temperature of about 12°C., and the rate of growth at a soil temperature of 15° to 16°C., as the following summary will indicate, is fairly rapid. Experiments with seedlings, at a soil and air temperature of 15° to 16° C., were conducted for a period of 114 hours with root growth as follows: 8.5 mm., 15.5 mm., 8.3 mm., and 4.5 mm. What the upper limit of temperature for root growth may be was not learned although the following experiments at superoptimal soil temperatures indicate that growth goes on, although slowly, at a temperature of 41° to 42°C. Such experiments, that is, those above the "optimal" soil temperatures, were conducted at the following temperatures: 36°C., 38° to 39°C., and 41° to 42°C. with results that can be briefly presented. At a temperature of 36°C., the roots of four seedlings, which had an initial length of 10 to 14.5 mm., increased 10.6, 13, 13.2, and 15.8 mm. in length in a period of 12 hours. In two of the plants the maximum rate observed occurred 3 and 4 hours after the beginning of the experiment. Following this rapid growth the curve was a fairly level one. It was notable that the gradual increase in rate, covering a period of several hours, which, as will appear below, was observed at lower temperatures for young roots, did not take place. Four of the plants which had been used three days previously in the experiment above sketched were subjected to a soil temperature of 38° to 39°C. for 12 hours. The roots of these plants grew 6.7 mm., 8.0 mm., 8.0 mm., and 7.2 mm. The root of another plant, not previously used, during the same time increased 13.5 mm. in length. The experiment was repeated with three plants, which had been used in both the preceding experiments, and with a fresh one not previously used, at a temperature of 41° to 42°C., with the following results. In 6 hours the roots of the used plants grew 0.1 mm., 0.9 mm., 2.7 mm., and 2.8 mm., while that of the fresh plant increased 4.3 mm. in length. It is apparent, therefore, that 41° to 42°C. is not, for a period of 6 hours, the maximum temperature for root growth in mesquite seedlings. The curve of growth, after the first 2 hours, was fairly level, although it is questionable whether this rate would have been maintained many hours.

Root growth at soil temperatures between 28.5°C. and 34.4°C. Most of the experiments reported at this time were conducted at temperatures clearly favorable for the growth of the roots of mesquite. Observations were made every 3 hours and the experiments extended over a period from 11 to 144 hours. The experiments are numbered for convenience from I to XIV. Table 1 gives the soil and air temperature, when known, together with the duration of each experiment.

TABLE 1

NUMBER OF EXPERIMENT	SOIL TEMPERATURE	AIR TEMPERATURE	DURATION OF EXPERIMENT
	°C.	°C.	hours
I	30–31.5	Room temperature	11
II	32–33.5	Room temperature	12
III	28.5	Room temperature	81
IV	28.5	Room temperature	93
V	30.5	20–24	66
VI	34.2–34.4	Room temperature	45
VII	31.5	22–24.5	48
VIII	31.5	30.5–32	51
IX	32–32.7	31–32.5	36
X	31.5	29.8–30.2	45
XI	31.5	30–31	48
XII*	15.5–16	16	196
XIII	35–35.5	16	96
XIV	24	16	144

(*) In experiments XII, XIII and XIV readings were made twice daily.

Root growth at a soil temperature of 28.5°C. Two series of experiments were conducted at a soil temperature of 28.5°C. in one of which the initial root length was 20 to 22 mm., and in the other the length of the roots at the beginning of the experiment was 3.8 to 5.8 mm. In the experiment with the shorter roots the rate of growth increased during the first 45 hours or more, and then declined or remained approximately constant. In the experiment with the longer roots the rate of growth increased up to 30 hours, more or less, when it decreased or remained about constant.

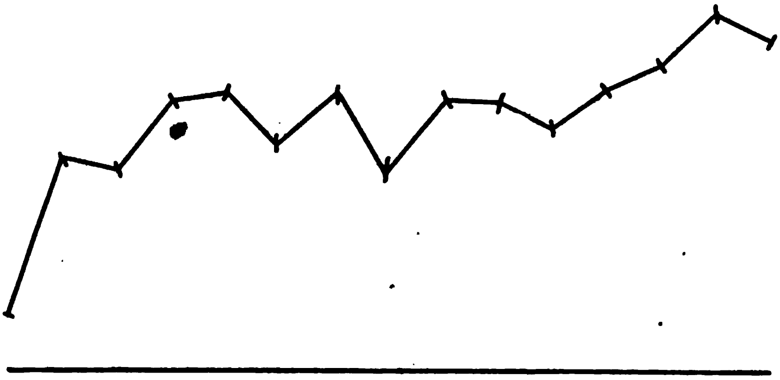

Fig. 1. Root growth of mesquite seedling, experiment VII, plant no. 46. Temperature of soil, 31.5°C. The initial root length was 16 mm. Readings every three hours. Growth × 15.

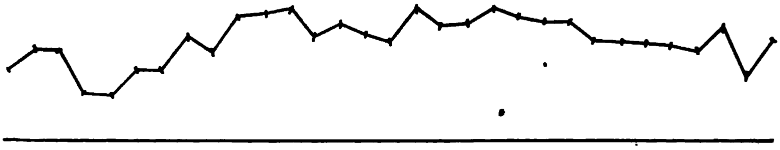

Fig. 2. Root growth of mesquite seedling, experiment IV, plant no. 26, temperature of soil 28.5°C. Initial length of root was 38 mm. Readings at intervals of three hours. Growth × 30.

A comparison of the character of curves made from the two groups of measurements indicates that the crest of the curve was reached sooner in the longer roots than in the shorter ones, and also that the growth rate varied more from reading to reading—at 3 hour intervals—in the shorter than in the longer roots.

Root growth at a soil temperature of 30.5°C. The initial length of the roots in the experiment at a soil temperature of 30.5°C., was between 41 and 62 mm. In each instance the rate of growth increased for 18 hours, more or less, and then decreased. In the specimen with the longest roots, approximately the maximum rate was attained within 6 hours after the beginning of the experiment, after which the rate was fairly uniform for about 30 hours and then declined. On the whole the curves of root growth in this experiment resemble the curves for growth of the longer roots in the previous experiment.

Root growth at a soil temperature of 31.5°C. Four series were run at a temperature of 31.5°C. In these experiments the roots of Nos. VII and XI had an initial length between 10 and 18 mm., those of No. VIII a length between 12 and 32 mm., and those of No. X an initial length of 85 to 105 mm. The results in experiments here numbered VII and X, which are to be considered representative, are given in tables 2 and 3.

In the experiments where the initial root length is 32 mm. or less, it was observed that usually there was a well marked increase in the growth rate with the passage of time, and that the minor fluctuations in the rate of growth were, as a rule, very pronounced. The generalizations can also be made in regard to root growth of such plants as had roots that were from 85 to 105 mm. in length at the beginning of the experiment, that the minor variations in growth were as a rule not considerable, and also that the curve of growth did not show the growth increase with the elapse of time, that was observed in shorter roots. On the contrary the growth rate remained approximately constant or gradually became less. As a corollary to this it is of interest to note that the length of the roots in the former instance—that is where the initial length was shortest—was relatively great at the time of the most rapid growth. For example, in no. VII the root lengths were 38.3 to 63.2 mm. in length at this time; in the other experiments the root length at the time was variable, but usually they were relatively long. An examination of the notes accompanying the experiments shows that the variation is not to be associated with the passage of time, the possible fluctuations in temperature of the soil or of the possible variation in the water relations, and probably not with that of illumination. On the other hand it ap-

TABLE 2

Experiment VII, root growth of mesquite seedlings in millimeters

SOIL TEMPERATURE	AIR TEMPERATURE	HOUR FROM BEGINNING EXPERIMENT	NO. 60	NO. 61	NO. 62	NO. 63	NO. 64
°C.	°C.						
31.5	30	3	3.3	2.7	3.1	2.8	5.9
31.5	30	6	3.1	2.6	4.7	2.8	7.4
31.5	30.3	9	3.4	2.9	3.2	2.4	7.2
31.5	31	12	4.6	3.3	3.1	1.1	5.3
31.5	30.5	15	3.1	3.3	4.2	1.5	7.5
31.5	30.5	18	3.9	3.9	3.8	2.2	9.4
31.5	30.5	21	3.1	4.6	2.2	1.9	7.6
31.5	30	24	3.3	4.5	2.8	1.7	7.5
31.5	30	27	3.3	4.2	3.4	0.3	8.2
31.5	30	30	3.5	4.7	4.1	1.6	9.2
31.5	30	33	3.5	4.5	2.4	0.6	8.3
31.5	30	36	3.2	3.8	1.8	0.6	7.1
31.5	30	39	3.8	4.0	1.4	0.5	10.0
31.5	30	42	3.1	3.5	1.4	0.8	8.4
31.5	30	45	3.0	3.3	3.1	0.8	8.3
31.5	30	48	2.6	4.2	2.8	0.2	8.0

TABLE 3

Experiment X, root growth of mesquite seedlings in millimeters

SOIL TEMPERATURE	AIR TEMPERATURE	HOUR FROM BEGINNING EXPERIMENT	NO. 55	NO. 56	NO. 57	NO. 58	NO. 59
°C.	°C.						
31.5	30.0	3	0.9	1.8	2.4	2.8	3.7
31.5	30.0	6		2.1	1.4	1.8	3.2
31.5	30.0	9	1.4	1.5	0.8	1.0	2.4
31.5	30.0	12	1.8	1.5	0.5	0.7	3.5
31.5	30.0	15	2.0	1.1	1.0	0.8	3.8
31.5	30.0	18	1.9	1.9	1.0	0.6	2.9
31.5	30.0	21	2.0	1.2	1.7	1.1	2.8
31.5	30.0	24	1.6	1.1	1.3	0.5	2.8
31.5	30.0	27	1.5	2.2	0.7	0.8	1.6
31.5	30.0	30	1.4	1.4	0.8	0.7	1.7
31.5	30.2	33	1.3	1.0	0.8	0.5	1.9
31.5	30.2	36	1.3	1.0	0.8	0.3	1.8
31.5	30.2	39	2.0	1.1	0.8	0.5	1.8
31.5	30.2	42	0.1	0.5	0.6	0.0	2.0
31.5	30.2	45	1.0	0.3	0.5	0.3	2.2

pears probable that the roots which are about 50 mm. in length under parallel conditions, have a more rapid growth rate than roots that are either much longer or much shorter than 50 mm.

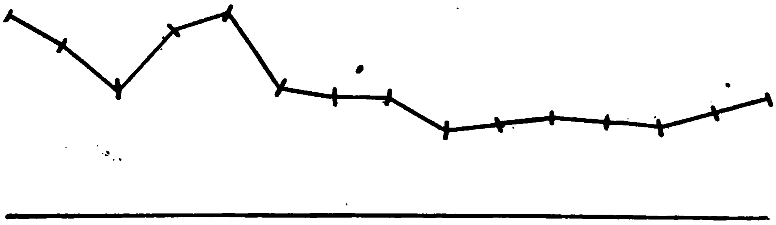

Fig. 3. Root growth of mesquite seedling, experiment X, plant no. 56. Soil temperature, 31.5°C. Readings every three hours. Initial length of root, 90 mm. Growth × 50.

Root growth at a soil temperature of 34.2°C. One series was run at a temperature of 34.2°C., which is to be considered very near the optimum for root growth in the mesquite. The experiment lasted 45 hours. The initial root length was between 1 and 6 mm. The rate of growth was seen to be extremely variable from observation to observation, but there was an increase in the rate up to about the eighteenth hour, or later, when the roots were between 35 and about 50 mm. in length. In the case of plant 40, however, and plant 44 as well, the maximum rate observed occurred within 6 hours after the experi-

TABLE 4

Root growth of mesquite seedlings at a soil temperature of 15.5° to 16.5°C., in millimeters. Twelve-hour periods

PERIOD	NO. 65	NO. 66	NO. 67	NO. 68	NO. 69	NO. 70
First	0.4	0.2	0.2	0.8	0.5	0.8
Second	1.0	0.6	0.1	1.5	0.7	1.8
Third	1.2	0.8		1.5	0.8	1.8
Fourth	0.9	1.2		1.7	0.5	1.5
Fifth	1.0	1.2		2.2	0.6	1.8
Sixth	0.9	1.3		1.4	1.3	1.7
Seventh	0.5	1.2		1.3	0.9	1.2
Eighth	0.2	0.6		1.9	1.3	1.5
Ninth		0.5		1.6	1.3	1.2
Tenth		0.9		1.7	0.4	1.2

TABLE 5

Root growth of mesquite seedlings at a soil temperature of 35°C., in millimeters. Twelve-hour periods

PERIOD	NO. 75	NO. 76	NO. 77	NO. 78	NO. 79
First*	11.0	13.5	12.5	19.6	14.5
Second	6.0	14.0	15.0	7.0	7.0
Third	6.0	17.5	12.5	14.5	10.0
Fourth†	5.0	16.0	18.0	11.0	5.5
Fifth	4.0	16.5	14.0	12.0	5.5
Sixth	2.5	11.0	11.0	6.5	4.5
Seventh	3.0	10.0	11.0	2.0	2.0
Eighth	2.5	7.0	7.0		2.0
Ninth	2.0	2.5	4.0		
Tenth	1.5	2.0	5.0		

* First fifteen hours after setting up the experiment.

† Fourteen hours interval.

TABLE 6

Root growth of mesquite seedlings, soil temperature 24° to 25°C., in millimeters, for 12 hour periods

PERIOD	NO. 80	NO. 81	NO. 82	NO. 83	NO. 84	NO. 85
First	10.0	3.5	7.5	3.5	5.5	8.0
Second	8.0	3.5	5.0	3.0	5.5	4.5
Third	11.0	3.0	3.0	1.7	6.0	5.5
Fourth	14.5	3.5	3.0	1.7	8.0	8.0
Fifth	11.0	7.0	3.0		9.5	9.5
Sixth	11.5	7.5	1.0		13.5	7.5
Seventh	10.5	8.0	1.0		12.5	7.0
Eighth	10.0	6.0	1.5		8.5	3.5
Ninth	9.5	8.5	1.5		5.0	3.0
Tenth	8.0	9.5	3.0		7.0	
Eleventh*	8.0	5.0	2.5		5.0	
Twelfth*	8.0	5.0	2.5		5.0	

* Average of two readings.

ment started. In plant 41 three high growth points appear on the curve, and they are of about the same value. In 45 hours the root of plant 41 increased 110 mm. in length. This, however, is not the highest rate of root growth observed in the species. The root of one plant, not elsewhere reported on in this paper, grew 51 mm. in 12 hours, which is the most rapid rate seen during the experiments. This occurred at a soil temperature of 32.5° to 34°C., or slightly lower than the temperature of the experiment referred to in this paragraph.

Root growth at an air temperature of 15.5° to 16.5°C. Three experiments were planned in which the air temperature was the same, 15.5° to 16.5°C., but the temperature of the soil was unlike. In the first one (no. XII) the soil was of the same temperature as the air, in the second (no. XIII), it had a temperature of 24° to 25°C., and in the third (no. XIV), the temperature of the soil was 35°C. Readings were made every 12 hours. The cultures were kept in a dark chamber which was illuminated with one 100-watt nitrogen electric bulb placed about 2 meters from the plants. The leading results are summarized in tables 4, 5 and 6.

The length of the roots at the beginning of the experiment was as follows: no. 65, ?; no. 66, 20 mm.; no. 67, ?; no. 68, 24 mm.; no. 69, 22 mm.; no. 70, 20 mm.

The initial length of the roots in experiment XIII, table 5 was as follows: no. 75, 30 mm.; no. 76, 65 mm.; no. 77, 70 mm.; no. 78, 73 mm.; and, no. 79, 65 mm. In experiment no. XIV, table 6, the root length at the beginning of the observations was as follows: no. 80, 12 mm.; no. 81, 5 mm.; no. 82, 10 mm.; no. 83, 8 mm.; no. 84, 8 mm.; and no. 85, 8 mm.

An inspection of tables 5 and 6 will show that, with the exception of no. 82, an acceleration of growth takes place until a well marked optimum, occurring a considerable time after the commencement of the experiment, is attained. This is followed by a gradual slowing in the rate. In the case of experiment XIII, table 5, the conditions both of temperature and of root length have operated to bring about a different result. Not only is the rate of root growth greater, but, also, the most rapid rate occurred at or near the beginning, and then gradually became less. It is suggested that the rapid growth rate as well as the decline in rate soon after the beginning of the experiment are not solely associated with the relatively high soil temperature to which the roots were subjected, but that the roots were not far from the period of most active growth, the "grand period," and that this period may have been passed during the experiment. However, it is impossible to differentiate between the two, and other factors, peculiar to the method used, may have been in operation as well.

VARIATION IN THE RATE OF GROWTH

Three types of growth variation in the roots of the mesquite were observed. Of these two are associated with every root whose growth was studied, and one type appears to be dependent on the length of the root. The first two types may be called the major and minor fluctuations in rate. They are of few or many hours duration, and do not determine the distinguishing character of the growth curve, which is determined by the third type of variation. This can be characterized briefly. Generally speaking roots whose initial length at the commencement of observations are 50 mm., or less, in length, show a gradual acceleration in the rate of growth for several hours, after which the rate decreases. In roots which are 50 mm. in length, or more, on the other hand, such acceleration appears not to be present, but on the other hand, the rate either remains fairly constant, or it decreases gradually. It should be noted that the length 50 mm. is only approximate and probably varies considerably. Another characteristic of the growth curve of the young mesquite roots, as contrasted with that of the older roots, is the greater amplitude of the major and minor growth variations as above described.

So far as the variation in rate of root growth in mesquite for the temperatures used is concerned, this can be summarized in a moment. In table 7 the average hourly maximum and minimum rate for the same individual is given. In all cases the maximum rate is the highest observed in the experiment, but, *per contra*, the minimum may, or may not be the least observed. The figures give, however, the actual range in the variation rate for the *individual* and at the temperature given.

Although the leading conclusions as above given do not harmonize clearly with the results of recent workers in this field, whose results also are not in close accord, they, however,

TABLE 7

Average hourly maximum and minimum rate of root growth of the same individual, in millimeters

SOIL TEMPERATURE	NUMBER OF EXPERIMENT	MAXIMUM	MINIMUM
°C.			
16.0	XII*	0.16	0.05
24.5	XIV*	1.12	0.4
35.0	XIII*	1.45	0.16
28.5	III†	2.2	1.2
28.5	IV	3.2	1.06
30.5	V	2.6	0.76
31.5	X	1.2	0.53
31.5	XI	3.3	1.7
31.5	VIII	2.06	0.56
31.5	VII	2.5	0.83

* Average of 12 hours.

† This and subsequent rates are average of 3 hours.

suggest a rational basis for agreement. The writers referred to are Leitch[1] and Lehenbauer[2] to whose work the reader is referred for literature covering the subject. Leitch used the roots of seedling *Pisum* and Lehenbauer the shoots of seedling maize. The third day after germination Leitch selected for study plants with roots about 15 mm. long and such as were the most uniform. This was at, or after the time of most active growth, and not before this time. Although Lehenbauer did not manipulate his experiments with direct reference to the "grand period," his procedure was uniform and it may have had a fairly constant reference to such period. The growth of shoots which were 10 to 12 mm. in length was studied. Abnormal individuals were eliminated. The duration period of the experiments was 39 hours or less. These workers obtained, results differing somewhat in character. Leitch found among other things a fairly constant growth rate for any temperature, while, on the other hand, Lehenbauer found the rate to accelerate at first and thus that the "maximum" rate was not the rate at first noted. The results of the present study, in which young as well as relatively old roots were used and in which the experiments were continued over a relatively long period, suggest that possibly the differences in results obtained by the two writers may lie in the possible differences in the organs studied with respect to the period of most active growth, that is, to the "grand period." Experiments conducted prior to this period would exhibit an increase in the rate of growth with the passage of time up to the attainment of the maximum rate at the crest of the "grand period." And, on the other hand, experiments conducted after the passing of the "grand period," would show a fairly level growth curve, or a descending one.

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[1] Some experiments on the influence of temperature on the rate of growth of *Pisum sativum*. Ann. Bot., **30**: 25, 1916.

[2] Growth of maize seedlings in relation to temperature. Phys. Researches, **1**: 247, 1914.

BOOKS AND CURRENT LITERATURE

HANDBOOK ON ALGAE.—In this,[1] the most important work of a general character on algae since the appearance of Oltmanns' Morphologie und Biologie der Algen in 1904–1905, the author treats the Myxophyceae (48 pp.), the Peridinieae (33), the Bacillarieae (23), and the Chlorophyceae (291). In addition 33 pages are devoted to the occurrence and distribution of freshwater algae.

After each division of the work a good bibliography is given, though these extend for the most part only to 1913, and in some instances to 1912. They indicate in a telling way the points of most active algological research at the present time. For example, under the Akontae 51 references are dated prior to 1900, while only 39 are more recent. On the other hand, the chapter on occurrence and distribution furnishes only 16 titles before 1900 and 62 of later date. It is a pity that in a book of this character the treatment is not brought more nearly up to date. This fault is, however, remedied to a slight extent by cursory mention in the Addenda (3 pp.) of a baker's dozen of titles from 1913 to 1916. A satisfactory index closes the volume. The size of the book properly precludes treatment of the Phaeophyceae and Rhodophyceae. However, in the judgment of the reviewer it was a mistake not to attempt at least a summary of modern work on the Flagellates, a group the importance of which is attested by a cloud of witnesses in recent years.

Throughout the work the author's leaning toward taxonomy finds expression, so that this side of the subject is emphasized at the expense of morphology and physiology. This is shown in the failure in many cases to present cytological results, though their importance is freely granted. As examples of such omissions, the work of Tröndle on *Spirogyra* (1911) and of Tuttle on *Oedogonium* may be mentioned.

The treatment of the Blue-Greens gives a satisfactory critical summary of previous work. The author suspends judgment on most of the familiar controversial points in this group, although on occasion he speaks his mind freely, as for instance in dismissing the work of Kohl,

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[1] West, G. S., Algae. Cambridge Botanical Handbooks (edited by A. C. Seward and A. G. Tansley), Vol. I. Pp. 475, figs. 1284. Cambridge University Press, 1916 (25 shillings).

Olive, and Phillips on mitosis as being the "result of unconscious self-deception" (p. 9).

In the discussion of Gaidukov's theory of "complementary chromatic adaptation" no reference is made to the physiological work bearing directly on this question, that of Dory and of Schindler particularly.

The classification of the Myxophyceae is given in full very much as in the author's British Freshwater Algae (1904), though the detailed treatment extends only to the families, with remarks on the important genera. This is the method used throughout the book. The absence of analytical keys and generic descriptions, which proved so useful in the earlier work, will be disappointing to users of the present book especially as the British Freshwater Algae is now out of print.

The author clings to his notion that *Glaucocystis* should be included in the Myxophyceae, though its color seems to the reviewer to be more than counterbalanced by other and more convincing characters. The author himself is at pains to point out that color is too variable in the group to be relied on. Indeed, he naïvely uses this fact as an argument against the name Cyanophyceae, not mentioning the well established priority of Myxophyceae as a reason for its retention.

The section on Peridinieae will be hailed with a glad cry by many botanists. Here we find presented, in excellent and well digested form, the first general account of the group in English. Many points of general interest, such as Kofoid's work on mutation in *Ceratium*, are here made readily available. No phase of the subject is neglected.

Equally good, though not filling such a crying want, is the section on Bacillarieae. Such accounts as this of the biology of the Diatoms are most welcome to the limnologist, and will be of great service when we get around to a scientific study of fish culture in fresh waters.

The Chlorophyceae are given a general introduction of 28 pages, which includes an excellent summary of the principal systems of classifications thus far proposed. The more detailed treatment is reserved for the subdivisions of the group. These subdivisions reflect the changes in the point of view of the author since the publication of his earlier book in 1904. At that time he divided the Class Chlorophyceae into nine orders. The Heterokontae were ranked as a coördinate class. In the present work, however, the Chlorophyceae are grouped in four "Divisions," the Isokontae, with six orders (Protococcales, Siphonales, Siphonocladiales, Ulvales, Schizogoniales, Ulotrichales); the Akontae (order Conjugales); the Stephanokontae (order Oedogoniales); and the

Heterokontae, with three orders (Heterococcales, Heterotrichales, Heterosiphonales). The order Microsporales of the older work is now made a family of the Ulotrichales.

It seems to the reviewer that the Heterokontae should have been retained as a separate class from the Chlorophyceae, since the differences between the two are thoroughgoing and far-reaching, and since the points of origin in the Flagellatae are considered for good reason to be different in the two groups. However, the subdivision of the Heterokontae is much more natural than in the older work, where only one order, the Confervales, was recognized. In this were lumped the most diverse families. The present satisfactory subdivision into three orders is modified from Pascher.

In general the classification adopted by the author is along the lines suggested by Bohlin and by Blackman and Tansley, differing in important points from the schemes of Oltmanns, Chodat, and Wille.

The material under the heading "Chlorophyceae" is so scattered in the different subdivisions that it is hardly possible to give a comprehensive review of it. Certain points may be commented upon. The statement (p. 138) that "no positive evidence of the reduction of chromosomes" has been brought forward in the case of *Spirogyra* is, of course, misleading, since Tröndle's paper in the Zeitschrift für Botanik, 1911, settles this question.

In the discussion of alternation of generations (p. 139) the chromosome number is accepted as the only factor in delimiting sporophyte and gametophyte. Thus the author says, granting the correctness of Allen's conclusions in *Coleochaete*, "It is scarcely possible to regard these post-natal phenomena [of the germination of the zygospore] as phylogenetic fore-runners of the sporophyte of the Archegoniates." No golden calf of old was ever worshipped with the fervor that many botanists of today exhibit for the chromosome. As an example of the lengths to which it may go the recent paper of Cunningham on *Spirogyra* may be cited (Bot. Gaz. **63**, p. 498), in which this remarkable conclusion may be found: "The filament of *Spirogyra*, in this species and those with lateral conjugation, is homologous with the sporophyte of higher plants." Here not even the substance, but the mere shadow of the chromosome frightens common sense and the reasoned conclusions of comparative morphology off the page. So with our author's treatment of the subject.

There follows a good discussion of polymorphism. Methods of culture given in this connection will be found useful (pp. 143–144). The culture medium of Chodat-Grintzesco might have been included with profit. The recommended addition of potassium chromate or potassium bichromate to the media has always been followed by disaster in the reviewer's cultures. Perhaps under very special circumstances such a procedure might be useful, but it certainly cannot be generally advised.

Space forbids the detailed discussion of the many interesting questions of classification occurring to the reader. One such point may be mentioned. The order Protococcales is broadly defined. The author seems quite justified in including here the *Volvox* series, though this disposition is not accepted by Collins, Oltmanns, or Pascher. The line between major groups must be sharply drawn. Those species of *Chlamydomonas* in which the habit is like *Palmella* and in which motile cells are only rarely produced are plainly Protococcaceous. *Chlamydomonas*, therefore, fits snugly in the Protococcales, and the other Volvocines must follow.

Our old friend *Pleurococcus vulgaris* has become *Protococcus viridis* Ag. Delimitation of the family of which this is the type is questionable. *Trochiscia* and *Chlorella*, other genera in the Protococcaceae, show important differences in reproduction from *Protococcus*. In fact, *Protococcus* may just as well be considered a reduced member of the Ulotrichaceae, which its "protoderma state" nearly resembles. *Trochiscia* and *Chlorella* fit equally well in the Autosporaceae.

The reviewer agrees with the author as to the phylogenetic history of the desmids. They are regarded as originally filamentous, then unicellular, and last in some cases secondarily filamentous.

The chapter on Occurrence and Distribution of Freshwater Algae suffers from having much of the material proper to it distributed elsewhere in the book. The chapter forms a good introduction to the ecology of the group. The objection may be raised that the factors influencing the occurrence and distribution of algae are not sufficiently emphasized. The truth is we know next to nothing about these factors, and material is lacking for their discussion.

The work as a whole is carefully done, and misprints and minor peccadilloes are rare. Guilliermond will probably be annoyed by the consistently odd spelling of his name, the pedant will feel a twinge on seeing "colonial unicells," the technician might object to the color reaction of cellulose with chlor-zinc-iodine being given as "blue"—all these in the first three pages—but the botanist will welcome with pleasure and profit this well arranged and comprehensive account of most of the algal groups. True, much of it may be found in the British Freshwater Algae, but a good deal is relatively new, and hitherto available only in special papers.

It is to be hoped that the series of handbooks, of which this is the first, will be carried forward with promptness and vigor. The usefulness of such reviews goes without question. The high price is unfortunate, as the number of readers will be lessened thereby. The book could be more cheaply produced without sacrificing its usefulness. However, the same might be said of Thuret's Etudes Phycologiques, now the delight of the botanical bibliophile.—I. F. LEWIS.

MEDULLARY RAYS.—The application of comparative anatomy to the criticism of other criteria of relationships is well exemplified in recent studies on the rays of coniferous woods. The sporadic occurrence of marginal trachoids in the rays of cupressineous woods was earlier observed by several workers, among them Penhallow, who seems to have misinterpreted them. The observation of such cells in a wounded stem of *Cunninghamia* by Jeffrey[1] set the matter in its true light, and this author interpreted the cells as a reversion to the ancestral condition seen for example in *Pinus*. Miss Gordon[2] reported ray tracheids in *Sequoia sempervirens*, and Miss Holden[3] showed that they occasionally occur in various genera of Taxodineae and Cupressineae. As to Abietineae, the earlier *Pityoxyla* lack marginal cells, while specimens from the Upper Cretaceous onward show them.[4] They are accordingly of comparatively recent introduction, and while prominent in all pines of the present era, they are apparently in process of disappearance in *Cedrus*,[5] and have practically disappeared from *Abies*,[6] and the Taxodineae and Cupressineae, though they may be recalled by wounding. Mention should be made in this connection of Thompson's theory of the origin of these cells.[7]—M. A. CHRYSLER.

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[1] Jeffrey, E. C. Traumatic Ray Tracheids in *Cunninghamia sinensis*. Ann. Bot. 22: 593–602, pl. 31. 1908.

[2] Gordon, M. Ray Tracheids in *Sequoia sempervirens*. New Phyt. 11: 1–7. 1912.

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NOTES AND COMMENT

An important gap in our knowledge of the developmental morphology of the Pteridophytes has been filled by Prof. A. Anstruther Lawson, of the University of Sydney, in his investigation of the prothallia of *Psilotum* and *Tmesipteris* (Trans. Royal Soc. Edinb., vols. 51, 52). This work gives us the first knowledge of the sexual generation of these relict genera, if we except the work of Lang, based on material which Professor Lawson now regards as having pertained to some plant other than *Psilotum*. The members of both genera are commonly epiphytic on arborescent ferns, and the brown rhizome-like prothallia were found on the rough fern trunks in several localities. The development is very similar in the two genera, and the vegetative characters and development are alike in presenting important differences from the prothallus of *Lycopodium*, as well as from that of *Equisetum*. The relationship of these plants to *Lycopodium* is therefore not so close as has been presumed, and strength is thereby given to the view already advanced by several workers that they have their closest affinities with the extinct Sphenophyllales.

The second part of Prof. W. F. Ganong's Textbook of Botany for Colleges has recently appeared (Macmillan, 1917). It is chiefly devoted to a description of the morphology and relationships of the great groups of cryptogamic plants and the orders of phanerogamic plants. The treatment is brief and general, but is accurate and down to date, and the illustrations are both numerous and excellent. A final chapter on the ecological classification of plants is well done, but it demonstrates how difficult it is to marshal the generalizations of ecology into a well-ordered presentation such as that given the facts of morphology. The appealing style in which the book is written should give it a field of utility outside the classroom, among that small and rapidly vanishing body of adults who read to improve their minds.

Around the Year in the Garden is a very practical and comprehensive book by which Mr. Frederick Frye Rockwell makes it possible for the man who is without a head gardener to carry out all of the operations of garden and lawn. It differs from other manuals of gardening published by Macmillans in having the chapters arranged so as to describe, week by week, the work of preparing hotbeds, sowing seeds, caring for growing plants, gathering the crop and storing it for home use. The book contains far too much information for its utility to be confined to the beginner.

Prof. William Trelease, of the University of Illinois, has prepared a compact booklet of 200 pages on the native and cultivated woody plants of the eastern United States (published by the author, Urbana, Ill.). There is a key to the genera embraced, and there are generic diagnoses, together with keys to the species. The book is designed primarily for the requirements of the gardener and the amateur, and will be valuable because of its concise but comprehensive character.

A text-book for the half-year course in botany in high schools is being prepared by Dr. E. N. Transeau, of Ohio State University. It will be published by the World Book Company as one of a series of new high school texts which is appearing under the editorship of Prof. John W. Ritchie.

The paper by Dr. Howard E. Pulling entitled The Rate of Water Movement in Aerated Soils, to which the first prize was given in the soil physics competition instituted by The Plant World, has been published in the September issue of Soil Science for the present year.

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THE INTERPRETATION AND APPLICATION OF CERTAIN TERMS AND CONCEPTS IN THE ECOLOGICAL CLASSIFICATION OF PLANT COMMUNITIES. II

GEORGE E. NICHOLS

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THE UNIT OF VEGETATION WITH REFERENCE TO PHYSIOGRAPHY

The edaphic formation. As has been stated earlier, from an ecological point of view the fundamental unit of vegetation is the association, the ecological aspect of which is determined by the habitat. Now in any given climatic region the habitats are not distributed indiscriminately. They are grouped, as has just been suggested, into more or less definite complexes, the boundaries of which are determined primarily by the physiographic features of the region. In brief, the various habitat complexes are associated with specific physiographic unit areas. From the standpoint of the physiography of the region as a whole, these habitat-complexes determined by physiography represent edaphic divisions of a higher order than the habitat; and likewise, from the standpoint of the physiographic ecology of the region concerned, the association-complexes which occupy these physiographic divisions represent vegetational divisions of a higher order than the association. Just as a ravine, a salt marsh, a rock hill, or a sand-plain may be regarded in its entirety as a physiographic entity, so its vegetation, taken in its entirety, is to be regarded as an entity from the standpoint of physiographic ecology. In other words, just as the association can be regarded as a unit with reference to a specific physiographic unit area, so the association-complex, where it is determined by physiography, can be regarded as a unit with reference to the physiography of the region. This physiographic unit of vegetation may be designated the edaphic formation. The edaphic formation may be defined as: an as-

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sociation-complex which is related to a specific physiographic unit area.

The developmental concept of the edaphic formation. The so-called developmental concept of the formation was first suggested by Moss who, in his account of the geographical distribution of the vegetation of Somerset (16, p. 12; *fide* Clements, 4, p. 118), states that: "The series of plant associations which begins its history as an open or unstable association, passes through intermediate stages, and eventually becomes a closed or stable formation, is in this paper termed a plant formation."[1] In a later paper (17, p. 36) he defines the [edaphic] formation as comprising "the progressive associations which culminate in one or more stable or chief associations [= edaphic climax associations], and the retrogressive associations which result from the decay of the chief associations, so long as these changes occur on the same habitat." This concept of the formation has been adopted by the Committee for the Survey and Study of British Vegetation (see 21, p. IX), and the edaphic formation is so interpreted by the writer, except that he would substitute "physiographic unit area" for "habitat" in the definition just quoted.

By some ecologists the edaphic climax association alone is treated as a formation. In the opinion of the writer, however, not the edaphic climax association, but rather the entire association-complex should be regarded as constituting the physiographic unit of vegetation: the edaphic formation. The edaphic climax association represents merely the culminating phase of a specific successional series: the most mesophytic type of vegetation capable of attainment in a specific physiographic unit area. It is the indicator, so to speak, of the degree of mesophytism which is attainable within the edaphic formation. As Moss expresses it (16, 17), it is the "chief" association of a successional series. It should be stated once more that the edaphic climax association of an edaphic formation may or may not coincide with the regional climax association-type.

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[1] The term formation is used by Moss in the sense that the term edaphic formation is used by the writer.

Primary and secondary edaphic formations. The term *secondary* is here used with reference to edaphic formations in which the vegetation has been modified by factors other than those which are attributable to biotic (not including human) or physiographic agencies. Formations whose vegetation has not been so modified are regarded as primary. Secondary edaphic formations commonly arise through the partial or complete destruction of the original vegetation by fire, lumbering operations, or cultivation.

The edaphic formation-type. In any climatic region, owing largely to the existence of numerous parallel series of physiographic unit areas, there have been developed correspondingly numerous parallel series of edaphic formations. Different individual formations which are correlated with the same type of physiographic unit area may be referred to a common edaphic formation-type; thus: ravine formation-type, rock hill formation. type, sand plain formation-type, etc. Like the association-type, the edaphic formation-type is an abstract conception. It may be defined as a type of edaphic formation correlated with a given type of physiography. As in the case of the association-type, the conception of the edaphic formation-type may be extended beyond the boundaries of a given climatic region. Thus, the ravine, or the flood-plain, or the salt marsh formation-type of one region may resemble that of another; etc. Edaphic formation-types are referred to in terms of the physiographic unit.area concerned, as has been done above.

The classification of edaphic formations. Although worked out from a somewhat different point of view and therefore somewhat differently formulated, the developmental concept of the edaphic formation was one of the fundamental features of Cowles' physiographic classification of plant associations (8, 9). Cowles was the first to fully appreciate the significance of physiography in relation to the local distribution of plant associations. "The keynote," he writes (9, p. 8), "is that each particular topographic form has its own peculiar vegetation. This is due to the fact that the soil conditions upon which plants depend are determined by the surface geology and the topography." He further states that, "From the standpoint of the vegetation the topographic relations are more important than the geological. . . . all kinds of soils may have the same kind of vegetation when placed in similar topographic conditions, whereas the same soil may show many diverse types of vegetation."

In classifying the edaphic formations within a given climatic region, topography, as related to the physiographic history of the region, is of fundamental importance. For, using this as a basis, it is possible to bring out the developmental relations of the physiographic unit areas involved, in much the same way that the classification of associations with reference to the phenomenon of succession brings out the developmental relations of the habitats concerned. It should be reiterated however, that while the contemporaneous features of the physiography of any region are the result of progressive development in the geologic past, from the standpoint of present-day physiographic ecology, with the exception of the relatively few areas in which changes manifestly are taking place rapidly, the physiography can be regarded as stable. That, on the whole, from the viewpoint of dynamic physiographic ecology, soil is of subsidiary importance to topography in determining the character of the vegetation seems obvious. But that soil may also exert a far-reaching influence on the ecological character of the vegetation is emphasized by the survey of vegetation set forth in "Types of British Vegetation" (21) where the formations are classified primarily with reference to soil. In general, then, the writer would classify the edaphic formations (1) with reference to topography, and (2) with reference to soil.

The edaphic formation-complex. The edaphic formations of any area, taken collectively, may be regarded as an edaphic formation-complex. And just as the association-complex of a physiographic unit area constitutes an edaphic formation, so the edaphic formation-complex of any climatic region constitutes a *climatic formation.*

THE UNIT OF VEGETATION WITH REFERENCE TO CLIMATE

The climatic formation. Climatic factors determine the larger features of the plant covering of the earth. Owing to widespread differences in climate, there are correspondingly widespread differences in the general ecological aspect of vegetation. The vegetation of any region in which the essential climatic relations are similar or uniform throughout, taken in its entirety, is here regarded as constituting a climatic formation. The climatic formation, then, bears a similar relation to the climate of the earth that the edaphic formation bears to the physiography of a climatic region; a similar one to that which exists between the association and the habitat-complex of a physiographic unit area. In other words, if the association is the ecological unit of vegetation from the standpoint of the habitat, and the edaphic formation is a unit from the standpoint of physiography, then the climatic formation is a unit from the standpoint of climate. Individual climatic formations are usually designated by combining the name of the geographic region concerned with that of the climax association-type of the formation; thus: the deciduous forest formation of eastern North America, the Great Plains short-grass formation, the sage-brush desert formation of the Great Basin.

The developmental concept of the climatic formation. Clements (4, pp. 3, 124–127) has adopted the developmental concept of the formation with reference to the climatic formation (in which sense he uses the word formation). He states that, "The unit of vegetation, the climax formation, is an organic entity. As an organism, the formation arises, grows, matures, and dies. Its response to the habitat is shown in processes or functions and in structures which are the record as well as the result of these functions. Furthermore, each climax formation is able to reproduce itself, repeating with essential fidelity the stages of its development. The life-history of a formation is a complex, but definite process, comparable in its chief features with the life-history of an individual plant. The climax formation is the adult organism, the fully developed community, of which the initial and medial stages are but stages of development. . . . A formation, in short, is the final stage of vegetational development in a climatic unit. It is the climax community of a succession which terminates in the highest life-form possible in the climate concerned. . . . It is delimited chiefly by development, but this can be traced and analysed only by means of physiognomy, floristic and habitat."

It will be seen from the foregoing quotation that Clements regards as the climatic formation what from the writer's point of view would be termed the regional climax association-complex (or association-type). It is the opinion of the writer that the climax association-complex should not be so regarded, but that the entire edaphic formation-complex of the region, or, as before stated, the vegetation of the region in its entirety, should be considered as constituting a unit from the standpoint of regional physiographic ecology. It seems more logical to regard the climax communities of the region, like other ecologically parallel series of communities, as belonging to a common association-type. As the most mesophytic type of vegetation attainable under the existing climatic conditions, the climax association-type may be looked upon as the climatic indicator, but not as the climatic formation. To sum up, the vegetation of any region having an essentially uniform climate throughout, taken in its entirety, constitutes a climatic formation, the general ecological aspect of which is determined by that of the climax association-type of the region.

The advisability of using the terms: edaphic formation and climatic formation. In a review of Clements' "Plant Successions," Tansley (22, p. 203) objects that if the concept of formation is restricted to a climax stage determined by climate, then "it leaves out of account the establishment of permanent communities of distinct life-form owing to edaphic conditions or to conditions determined by biotic reaction on the soil. It was to cover cases of this kind that Schimper introduced the term edaphic formation, and if its use be not allowed it is difficult to see how we are to classify such communities." Schimper (19, p. 161) says that "two ecological groups of formations should be distinguished—the climatic or district formations, the character of whose vegetation is governed by atmospheric precipitations, and the edaphic or local formations, whose vegetation is chiefly determined by the nature of the soil."

It is the opinion of the writer that the only logical way to reconcile the divergent views of various authorities regarding the interpretation of the word formation is to retain the classification of Schimper, distinguishing between edaphic formations on the one hand and climatic formations on the other, but modifying Schimper's concept to harmonize with the developmental concept as set forth in preceding paragraphs of this paper:

The climatic formation-type. On different portions of the earth's surface, owing to the existence of various parallel types of climate, there have been developed correspondingly numerous parallel types of climatic formation. Thus, as delimited on Schimper's map (19, map 3), the sclerophyllous woodland formation of southern California is paralleled by the sclerophyllous woodland formation of the Mediterranean region and that of South Africa. Similarly, the short-grass formation of North America finds its ecological counterparts in the grassland formations of Russia and China. Different individual climatic formations which have thus developed in response to the same type of climate and which as a result agree with one another in their ecological aspect, even though they differ (as they usually do) in their floristic composition, are to be considered as belonging to the same climatic formation-type. Like the association-type and the edaphic formation-type, the climatic formation-type is an abstract conception. It may be defined as: a type of climatic formation correlated with a given type of climate. While, in practice, their exact delimitation is of course a matter of considerable difficulty, in a general way it is possible to divide the vegetation which clothes much of the earth's surface into a relatively small number of formation-types.

Brockmann-Jerosch and Rübel, in their universal classification of plant communities (2) have distinguished four vegetation-types (lignosa, prata, deserta, and phytoplankton) and have further subdivided the plant formations of the earth into fourteen formation-classes and seventeen formation-groups. They do not, however, restrict the use of these terms to climatic formations: under prata, for example, are included the salt marshes and fresh marshes of forested regions, as well as the climatically-conditioned grassland formations. The word formation-type, from the standpoint of regional physiographic ecology, is here used only with reference to climatic formations. Schimper (19) has used the term in this sense, distinguishing three chief types of climatic formations (woodland, grassland, and desert) as well as various types of subordinate rank. Climatic formation-types, like climatic formations, are best designated in terms of the ecological aspect of the vegetation, as has been done in the illustrations cited above.

The climatic formation-complex. In treating the vegetation of any large area, such as the continent of North America, where more than one type of climate and correspondingly numerous different climatic formations are represented, the term climatic formation-complex may be used to include collectively the climatic formations of the entire area. The climatic formations comprising the complex may be genetically related in point of geologic time, as in the glaciated parts of eastern North America, but the term does not necessarily imply such a relationship. The climatic formation-complex of the earth, taken in its entirety, might be regarded as forming a *terrestrial formation.*

The application of the law of the minimum in regional physiographic ecology. In applying the Law of the Minimum to problems in local physiographic ecology, climatic factors need not be taken into account since they are essentially constant throughout the region. The variable factors are edaphic; they are due, directly or indirectly, to variations in either soil or topography. In dealing with problems in regional physiographic ecology, however, where the climatic factors also are variable, these of course are of paramount importance. Precipitation, the evaporating power of the air, temperature, and light afford the chief limiting factors, the factors which determine the general aspect of the vegetation in a climatic formation.

Even here, however, the edaphic limiting factors, at least in some cases, may be of great significance, and it need be only suggested that in an accurate analysis these, as well as the climatic limiting factors, must be considered.

SUMMARY

By way of summary, it may be stated that the fundamental unit of vegetation is the association. The associations of a unit physiographic area, taken collectively, constitute an edaphic formation. The edaphic formations of a unit climatic area, taken collectively, constitute a climatic formation. The climatic formations of the earth, taken collectively, may be said to constitute the terrestrial formation. The association is a unit determined by habitat, the edaphic formation a unit determined by physiography, the climatic formation a unit determined by climate, while the terrestrial formation might be said to be a unit determined by the atmosphere. "The conception of a formation as an ecological genus and an association as an ecological species" (Cowles 10, p. 150) may be further amplified. If the association is regarded as an ecological species and the edaphic formation constitutes an ecological genus, then the climatic formation may be said to represent an ecological family, while the terrestrial formation might be regarded as a unit of a still higher order.

In the preceding pages the various ecological units of vegetation have been treated as an ascending series. Starting with the fundamental unit, the association, the units of a higher order have been treated in the order of their increasing complexity. Their relative rank and their relation to one another is brought out by the following synopsis.

The terrestrial formation: = the climatic formation-complex of the earth
  The climatic formation: = the edaphic formation-complex of a climatic unit region
    The edaphic formation: = the association-complex of a physiographic unit area
      The association: = the plant-complex (community) of a unit habitat

THE SCHEME OF CLASSIFICATION IN PRACTICE

Outline classification of the vegetation of northern Cape Breton Island. The practical application of the classification of plant communities according to the concepts enunciated in the foregoing pages will now be illustrated by a specific example. The vegetation of the area selected has been under investigation for four summers, and a full account of the writer's observations and conclusions here is in the course of preparation. Northern Cape Breton lies in the transition zone between the two great climatic formations of eastern North America: the deciduous forest climatic formation and the northeastern evergreen coniferous forest climatic formation, and, owing largely to differences of elevation, both of these are well developed, the former on the lowlands and the latter on the highlands. The scheme adopted in classifying the various edaphic formations which comprise the deciduous forest climatic formation here, is outlined below. Such a scheme, it should be borne in mind, answers much the same purpose in the realm of physiographic ecology as an analytical key in the realm of systematic botany. The classification has been carried as far as the ecological genus, i.e., as far as the group of associations which comprises an edaphic formation.

THE VEGETATION OF NORTHERN CAPE BRETON

The deciduous forest climatic formation

I. The regional climax association-type
II. The edaphic formation-complex of the region
    A. Primary formations of the xerarch successional series
        1. The formation-types of ordinary uplands
            a. The association-complexes of exposed rock outcrops
            b. The association-complexes of talus
            c. The association-complexes of glacial drift
        2. The formation-types of uplands along streams
            a. The association-complexes of rock ravines
            b. The association-complexes of open valleys
            c. The association-complexes of boulder plains
            d. The association-complexes of flood plains
        3. The formation-types of uplands along the seacoast
            a. The association-complexes of sea-bluffs and headlands
            b. The association-complexes of shingle beaches
            c. The association-complexes of sandy beaches and dunes

- B. Secondary formations of the xerarch successional series
        - a. Association-complexes due to cultivation
        - b. Association-complexes due to fire
        - c. Association-complexes due to logging
- C. Primary formations of the hydrarch successional series
    - 1. The formation-types of inland lakes and swamps
        - a. The association-complexes of permanent lakes and ponds
        - b. The association-complexes of periodic ponds
        - c. The association-complexes of well-drained swamps
        - d. The association-complexes of undrained swamps
        - e. The association-complexes of poorly drained swamps
    - 2. The formation-types of lakes and swamps along the seacoast
        - a. The association-complexes of salt and brackish marshes
        - b. The association-complexes of brackish ponds
- D. Secondary formations of the hydrarch successional series

The northeastern evergreen coniferous forest climatic formation

- I. The regional climax association-type
- II. The edaphic formation-complex . . . . etc.

Explanatory remarks. In attempting to make an ecological analysis of the climatic formation of a given region it seems logical that the subject matter be first arranged under two heads: (I) The regional climax association-type, and (II) The edaphic formation-complex of the region. This division has already been employed by Cooper (5), although he did not distinguish the edaphic formations as such. An understanding of the regional climax association-type, representing as it does the highest degree of mesophytism permitted by the climate, is prerequisite to the adequate interpretation of subordinate association-types and of successional relations. The term edaphic formation, given its developmental concept, of course includes the successions.

The various edaphic formations which comprise the regional edaphic formation-complex are next assembled into two successional series which, adopting the terminology suggested by Cooper (5, p. 11), are termed respectively the xerarch and the hydrarch series. The term xerarch, to quote Cooper "is applied to those successions which, having their origin in xerophytic habitats, such as rock shores, beaches, and cliffs, become more and more mesophytic in their successive stages; [the term hydrarch] to those which, originating in hydrophytic habitats, such as lakes and ponds, also progress toward mesophytism." The formations of these two series are further grouped as primary and secondary.

Considered next with reference to the larger topographic features[2] of the region, the edaphic formations of the xerarch series are divided into three groups: (1) The formation-types of ordinary uplands; (2) The formation-types of uplands along streams; (3) The formation-types of uplands along the seacoast. The edaphic formations of the hydrarch series are similarly grouped under two heads: (1) The formation-types of inland lakes and swamps; (2) The formation-types of lakes and swamps along the seacoast. They might equally well be divided into four groups: (1) The formation-types of glacial lakes and swamps; (2) The formation-types of sink-hole lakes and swamps; (3) The formation-types of river lakes and swamps; (4) The formation-types of coastal lakes and swamps; except that river lakes and swamps are scarcely represented in this region.

Finally, the association-complexes which comprise the various edaphic formations are further grouped with reference to whatever specific physiographic unit areas it seems best to distinguish. Under this head are considered the character and the successional relations of the individual associations and association-types. This latter part of the scheme in particular is so elastic and so capable of modification that it may be readily adapted to the special requirements of any region and to the individual views of any investigator.

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COMPARATIVE LENGTH OF GROWING SEASON OF RING-POROUS AND DIFFUSE-POROUS WOODS

FERDINAND W. HAASIS

Jenkins, Kentucky

The object of these studies was to answer the question: does the growth of so-called *diffuse-porous* woods continue after that of *ring-porous* woods has largely ceased; in other words, is the growth of the former distributed over a longer period than that of the latter?

The work was done during the 1916 growing season at Jenkins, Kentucky. A small number of trees of various species were selected growing under essentially identical conditions of site, and of these the growth in length of specific branches was measured, it being assumed that this would be a reasonable indicator of the diameter growth. The specimens were located on a 30 degree southeast slope, with rather rocky thin soil, the bedrock being a gray conglomerate: litter light, ground cover moderate, and including *Epigœa repens*, *Smilax rotundifolia*, grasses, moss, lichen, etc. The area was logged in 1911 leaving few older trees, and the specimens were practically in the open.

Measurements were made of the following trees with ring-porous wood: *Sassafras Sassafras*, *Quercus Prinus:* of the following with diffuse-porous wood: *Nyssa sylvatica*, *Kalmia latifolia*, *Acer rubrum;* and of the conifer: *Pinus rigida.* Two chestnut oaks were used, one situated almost directly on outcrop. Its total height was 43 cm., and it was branched all the way up, but with one distinct main stem. Measurements were made on a 7-cm. twig at the top. The other was an upright shoot of a semi-prostrate sprout 1.5 m. high and from the same stump as another 4 m. high. The growth was measured of a twig near the top, and 61 cm. in length. The sassafras was one of two seedling sprouts from the same root, and was 15 cm. high.

The red maple was one of about a dozen small sprouts from a 3-cm. stump. Measurements were made on two of three adjacent twigs respectively 49, 49 and 52 cm. long, at the end of an inclined sprout 133 cm. long. The longest was dead at the tip after growing 1 cm. by June 7. The mountain laurel was a bushy plant with two prominent branches. One of these, *a*, at the top, was 28 cm. long. The other, *b*, a side branch from near the base, was 16 cm. above the last main fork, and bore flower-buds. The black gum measurements were made on the largest of three seedling sprouts from the same root, respectively 40, 75, and 100 cm. long, the shortest being prostrate, the others

TABLE 1

Showing the total season's growth at the several dates of measurement

	APRIL 2	APRIL 16	APRIL 30	MAY 14	JUNE 7	JUNE 18	JULY 5	JULY 30	AUGUST 16	SEPTEMBER 10	OCTOBER 29
				cm.	*cm.*	*cm.*	*cm.*	*cm.*	*cm.*	*cm.*	*cm.*
Sassafras	n gr*	n gr*	n gr*	1	6	7	7	7	7	7	7
Quercus	n gr*	n gr*	n gr*	23	23.0	23	23	23.0	23.0	23.0	23.0
Quercus	n gr*	n gr*	1.5 c.m.	5	5.0	5	5		5.2	5.2	5.2
Nyssa	n gr*	n gr*	n gr*	5	27.0	31	32	32.0	32.0	32.0	32.0
Kalmia	n gr*	n gr*	n gr*	13	14.0	14		15.0	15.0	15.0	15.0
				16	17.0	17	17	17.0	17.0	dead	
Acer	n gr*	n gr*				1	1	1.0	1.0	1.0	1.0
						2	2	2.3	2.5	2.5	2.5
					1.0	tip dead					
Pinus	n gr*	n gr*	2.5	6	9.5		12	14.0	14.0	14.0	

* No growth.

TABLE II

Showing dates between which growth in length ceased

Sassafras	June 7	June 18
Quercus	April 30	May 14
Quercus	July 5	August 16
Nyssa	June 18	July 5
Kalmia	June 18	July 30
	May 14	June 7
Acer	July 30	August 16
Pinus	July 5	July 30

erect. The pine was growing on very poor soil, practically outcrop. It had a rather weak stem 95 cm. long bent into an arc of almost 90 degrees.

Table 1 shows the results of the measurements, and table 2 the dates between which the growth in length ceased. From the very few data collected, it seems that the plant forming the ring-porous wood does, indeed, finish its wood growth at an earlier date than that producing diffuse-porous wood. If this be true, may there not be some relation between the diffuseness of the latter's growing season and the lack of the extreme differentiation of tissue exhibited by the other? It is to be noted, though, that the diffuse-porous woods grew much faster earlier in the season than later on. In the case of the evergreen conifer the growing season is prolonged as in the diffuse-porous wood.

There are needed a larger number of parallel observations on this phenomenon; and the measurements should obviously be more frequent in the very early part of the season. It should not be overlooked that cessation of wood production does not mean that growth has ceased, for bud formation, and in some cases the maturing of fruit, continues considerably later than wood growth.

BOOKS AND CURRENT LITERATURE

Recent Investigations on Evaporation and Succession.—The appearance of Gates's paper on "The relation between evaporation and plant succession in a given area" has suggested the desirability of examining the conflicting views in this field. This task is made easier by the facts that methods and results are essentially in accord throughout. The divergence in the several investigations is limited to the conclusions drawn as to the rôle of evaporation, and it centers around the question whether evaporation is a cause or an effect. Fuller and Weaver regard evaporation as essentially causal to succession, a view which seems to be shared by Transeau in some degree. On the other hand, Gleason and Gates consider it merely a consequence of the increasing population and the resulting shade. A careful examination of their conclusions readily discloses the source of the disagreement, and serves to harmonize the results more or less completely.

Transeau[1] was not especially concerned with the dominants of the various communities, and his results do not bear directly upon the seral movement. Moreover, it cannot be said with certainty that he regards evaporation as causal, though the following statements seem to indicate this. "With these data in hand it is not difficult to see why seedlings of *Trillium*, *Arisaema* and *Veratrum* are successful in the swamp forest with its 10% relative evaporation; why they fail in the open hillside forest with its 50% rate; and why they are never seen on the near-by gravel slide with its relatives rate of 100% in addition to its unstable character."

"In the reforestation of the gravel slides in this locality it will be seen that the greatest decrease in the demands for transpiration on the part of seedlings takes place during the first stages. This greatly aids in accounting for the well-known fact that development toward a closed association proceeds with such increasing rapidity when once a few plants gain a foothold. Attention has been frequently called to the importance of pioneers as shade producers, while their effectiveness in reducing transpiration has been underestimated."

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[1] Transeau, E. N. The Relation of Plant Societies to Evaporation. Bot. Gaz. 45: 217. 1908

Fuller has made several studies of the relation between evaporation and plant communities, but only two of these deal directly with succession. In Evaporation and Plant Succession,"[2] his major conclusion is that "The differences in the rates of evaporation in the various plant associations studied are sufficient to indicate that the *atmospheric conditions are efficient factors in causing succession*."[3] It seems significant that the final comprehensive paper is entitled "Evaporation and soil moisture in relation to the succession of plant associations."[4] The conflict in opinions can be traced directly to the statement that "The evaporation thus controlled and changed is *one of the principal factors* in causing the development of a different vegetation, or in other words, the decreased rate of evaporation caused by the heavier vegetation is *the direct cause* of succession between different associations" (p. 199). The latter part of this statement would seem to be a slip of the pen if one may judge from the evidence afforded by the general conclusions and summary. "The progressive increase in the water-retaining power of the soil, due largely to its increased humus content, must play no inconsiderable rôle in causing the succession here culminating in the mesophytic beech-maple forest" (p. 231). "*These comparative values of the moisture factors* [ratios between evaporation and available water] show such a surprising rate of increase as one proceeds from the pioneer to the climax associations that it cannot be doubted that such a change in water conditions must be *one* of the chief factors, if not the *most important cause*, of the succession of associations from the more xerophytic to the more mesophytic" (p. 231). "*The evaporation rates and the amount of growth-water* in the various associations vary directly with the order of their occurrence in the succession, the pioneer being the most xerophytic in both respects. The *ratios between evaporation and growth-water* in the beech-maple forest, oak-hickory forest, oak dune, pine dune and cottonwood dune associations have been shown to have comparative values of 100, 65, 20, 17 and 15 respectively, and the differences thus indicated are sufficient to be *efficient factors* in causing succession."

Gleason and Gates,[5] working in the same general region as Fuller, reached the following conclusions. "Differences in the amount of evaporation in various associations, are due chiefly to the nature of the vegetation, which by its size and density controls the evaporation beneath it. *The observations indicate that successions between associations are not caused by any conditions of evaporation.* The more primitive associations have the higher rates of evaporation, while those most nearly like the climax type have the lowest rates. This is true not only for the forest associations, in which low evaporation is expected, but also for the prairie associations, which are correlated with an arid climate and consequently high climatic evaporation."

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[2] Fuller, G. D. Evaporation and Plant Succession. Bot. Gaz. **52**: 193. 1911.

[3] The italics here and later are the reviewer's.

[4] Fuller, G. D. Evaporation and Soil Moisture in Relation to the Succession of Plant Associations. Bot. Gaz. **58**: 193. 1914.

[5] Gleason, H. A. and Gates, F. C. A Comparison of the Rates of Evaporation in Certain Associations in Central Illinois. Bot. Gaz. **53**: 478. 1912.

Weaver[6] as a result of successional studies in the Palouse region of the Northwest, finds that "A study of the difference of the rates of evaporation in the various plant formations and associations shows that these differences are sufficient to be *important factors in causing* succession, at least through the earlier stages, where light values are usually high." Later, in a study of edaphic prairie in Minnesota and climatic prairie in Nebraska, Weaver and Thiel[7] summarize the reactions as follows. "If sufficient light is available, there is no question but that the *humidity of the air and the soil* are the *most important factors* affecting the establishment of the different plant communities. The progressive increase of the humidity of the habitat causes a corresponding increase in the mesophytism of the plant community. The evaporation rates and the amount of soil moisture of the various communities both in Minnesota and Nebraska vary in general directly with the order of their occurrence in the succession, the community nearest the climax being the most mesophytic in both respects."

Gates[8] has directed his attention primarily to the ecesis of the dominants of the various stages, and reaches the following results.

"Invasion, which is the initial stage of succession, must take place under the conditions already existing.

"The change of conditions coincident with mesophytic succession brings about a decrease in the rate of evaporation in the ground or chamaephytic layer.

"In a given area, the differences in the amount of evaporation under which seedlings develop are largely due to the surrounding vegetation, which by its size and density controls the evaporation beneath it.

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[6] Weaver, J. E. Evaporation and Plant Succession in Southeastern Washington and Adjacent Idaho. Plant World **17**: 273. 1914.

[7] Weaver, J. E. and Thiel, A. F. Ecological Studies in the Tension Zone between Prairie and Woodland. Rep Bot. Surv. Nebr. N. S. 1. 1917.

[8] Gates, F. C. The Relation between Evaporation and Plant Succession in a Given Area. Amer. Jour. Bot. **4**: 161. 1917.

"The complete range of evaporation conditions present in this region, namely, from bare ground to the mature forest, is completely within the physiological limits of the seedlings of *Acer saccharum*, *Pinus strobus*, *Pinus resinosa* and *Thuja occidentalis*. Given suitable soil conditions, maple seedlings will develop under evaporation conditions at least 337% more xerophytic than the normal hardwood forest, or 400% more xerophytic than the very dense forest.

"Within their soil requirements and in the presence of light, the establishment of the pine, beech-maple and Thuja bog associations is independent of any particular conditions of evaporation. *Consequently a decrease in evaporation is not a prerequisite to succession.*

"The change in the rate of evaporation from the chamaephytic layer is produced by the development in density of the invading vegetation. Being coincident with and not antecedent to it, *the change in evaporation is a result and not a cause of succession.*"

At the beginning of his paper, Gates quotes the opinion of Gleason and Gates, and the first statements of Fuller and Weaver, as given above, to show the discrepancy in the views on this subject. Fuller (1914, p. 199) evidently feels this also, for he says that "It seems surprising that Gleason has reached an opposite conclusion from somewhat similar data." In spite of this, however, the later statements of Fuller, as of Weaver, make it clear that they are thinking of evaporation not as a separate factor but in its normal relation to water content, a general principle with which the work and the conclusions of Gleason and Gates, and of Gates are in full accord. It seems probable, however, that Fuller and Weaver would emphasize the importance of evaporation in the complex of water relations especially in a dry region such as the Palouse, while Gleason and Gates evidently do not. It is clear that evaporation is an indirect or remote cause of succession, since it affects the adequacy of the water-content through transpiration as well as by loss from the soil. The direct or primary causes must be sought in the available water-content, which finally determines absorption and growth, and in light, which controls the food supply, to say nothing of its effect upon transpiration.

All of the above investigations have brought us appreciably nearer our goal in the study of succession. They all possess the distinct merit of dealing quantitatively with reactions in their causal relation to the seral sequence. They also serve to bring us closer to the realization of the fact that future research must deal with the complex of reactions and the exact rôle of each factor in the complex. The reviewer[9] has already emphasized these requirements of successional research, and it may be helpful to point out here the essentials of thorough-going quantitative study. It is obvious that the reaction-level, in which the seedlings of dominants occur, must be the main objective. In most cases, measurements of water-content and evaporation, and of light in the reaction-level of the various zones or stages will suffice, but all of these must be dealt with in the same investigation. In the oxysere, aeration and other factors must be studied, while in the halosere the chief attention must be given to the solutes. It is already apparent however that we must soon use the plant as an index of reaction. The transpiration of each dominant will prove by far the best measure of the control of water reactions, just as the amount of photosynthate and growth will be the best measure of seral response to light reactions. Perhaps the greatest need in the study of succession is the use of methods of sequence and experiment in place of the almost universal method of inference. It seems inevitable that the next great step in advance will be made by series of reaction quadrats, in which the interplay of development and reaction may be followed year by year, and where the actual fate of dominants can be checked by reciprocal experiments in ecesis.—FREDERIC E. CLEMENTS.

SOIL TEMPERATURE AND PLANT GROWTH.—The effects of soil temperature *per se*, as distinguished from that of the air, on the growth and development of plants, appears not to have received very much attention. The recent study by Halsted and Waksman[1] therefore, is of much interest. In this research two lots of corn were placed under observation. Of these one lot was grown between July 30 and August 26, and the other between October 29 and November 29, in a greenhouse which was not artificially heated. The temperature of the soil was noted twice daily, at 6 o'clock, morning and evening. For the summer the average temperature of the soil was 25.68°C. In the autumn the daily average was 12.87°C. The air temperatures are not given.

The title of the study does not give the idea that it is on heredity, or variation, as is the fact, and as such it has much interest, but the feature of the work to which the reviewer wishes to direct attention is that correctly connoted by the title, that is, to the influence of the temperature of the soil itself on the behavior of the plants without regard to the strains of corn employed.

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[9] Clements, F. E. Plant Succession. Carnegie Inst. Wash. Pub. 1916. Pp. 96, 421.

[1] Halsted, B. D., and Waksman, S. A. The Influence of Soil Temperature upon Seedling Corn. Soil Science 3: 393–398, 1917.

In judging the influence of warm and cool soils on seedling corn the following points were considered: viability, length of mesocotyl, emergence, length of plant, weight of seedlings, vigor of seedlings, and variability in length of seedlings. Among the leading results and conclusions the following can be noted: The summer-grown seedlings were 32.93% more viable than those that were grown in autumn. The mesocotyl was 10.9% longer in the seedlings grown in summer than in those grown in autumn. In summer the corn seedlings "came up" somewhat over 10 days sooner than in autumn, and the average emergence for the two seasons was 4.06 and 14.63 days, respectively. The length of the plants grown in summer was found to average 41.6 mm. while the length of plants grown in autumn was 11.7 mm. The average weight of the summer-grown seedlings was 4.27 grams while the average weight of the seedlings grown in autumn was 1.27 grams. As to the vigor of the seedlings, that is, "the weight of the crops less the seeds planted," it was found that the seedlings raised in summer averaged nearly four times as heavy as those grown in autumn. Thus in many respects the seedlings grown in summer are immensely more vigorous than those grown in autumn, but as regards variability, the autumn-grown seedlings ranked first. The variability in length of seedlings of summer was 1.08 per cent, while those that were grown in autumn had a variability in length of 2.32%.

Although it is thus shown that the shoots of the corn seedlings vary in development directly with the temperature of the soil, it would be of considerable interest to know whether the development of the roots of the two corn crops varied also and to what degree. That this would be the case would be expected, however, from the experience of other writers with other species. Indeed, it might even be not too much to suggest that a close study of root behavior under such conditions as those which obtained in the study in question, may have given results quite as applicable to the case, from the present point of view at any rate, as the study of the shoots only.

The work of Halsted and Waksman recalled to the reviewer a series of analogous experiments which he carried out on cuttings of *Opuntia versicolor* at the Coastal Laboratory, in which the soil only was heated, and the shoots of the plants were subject to the temperature changes incident to the experimental garden at Carmel. As is well known *O. versicolor* is native to southern Arizona and thus, in its proper habitat, is exposed to a warm summer climate. At Carmel, however, the temperature of the soil throughout the year is relatively low and so is that of the air. It was not especially surprising, therefore, to learn that shoot growth of the species scarcely ever occurs at the Coastal Laboratory. This being the case experiments were planned as suggested above, and the apparatus was arranged in the following manner. A root box was devised and constructed in such a manner that heat could be applied continuously at each end by using electric lamps. A part of one side was made of glass and sloped in such a way as would bring about the exposure of the roots. The entire box was well insulated, and the soil was closely covered with heavy building paper. The temperature of the soil was slightly above the optimum for the *Opuntia* at the ends of the box, and somewhat under the optimum at the middle, but between the two the temperature was, for the most part, close to 30°C. Several specimens were removed from the garden, where they had been quiescent for the entire season, and put in the box in early September. The culture was left under a protecting shade until late November during all of which time the soil was frequently watered and was kept heated in the manner suggested, and the shoots of the plants were exposed to uncontrolled air temperatures, which varied between 3.5° and 30°C. as extremes.

Such being the conditions of the experiment, the results can be stated in a word. Root growth of all plants in the soil where the temperature was most favorable was found, when the experiment was terminated, to have been very active, and the roots reached to the bottom of the box, or to a depth of 60 cm. All of the plants were found to have put on new shoots and fresh leaves. The shoots had much the appearance of having been "forced," and were 8 cm. more or less, in length. Thus it was shown that relatively great vegetative activity of *Opuntia versicolor* can be induced under unfavorably low conditions of air temperatures if the roots are kept at temperatures favorable for their growth. This result constitutes a rather interesting confirmation of the conclusions of Halsted and Waksman, although having reference to quite a different type of plant, and further emphasizes the importance of including soil temperatures in any definition of the physical characteristics of the habitat of a species.—W. A. CANNON.

NOTES AND COMMENT

The receipts of the National Forests for the past fiscal year exceeded those of the previous year by more than $600,000, and reached a total of $3,450,000. This sum is chiefly derived from the nearly equal sources of timber sales and grazing permits, with a small income from permits for water-power development. The cost of operating the forests remained approximately the same as in the preceding year at $4,000,000. The gradually increasing receipts give a basis to the hope that the National Forests will become self-supporting in the course of a few more years. During the last fiscal year the cutting of timber was more active and the number of cattle and sheep given pasturage was raised from 9,600,000 to 9,900,000, with slightly increased fees for grazing. The careful supervision that has been given to grazing operations in the National Forests for a number of years has resulted in such greatly improved conditions that it was deemed safe to allow an increase in the amount of stock pastured during the past summer as a war emergency measure.

Dr. H. C. Cowles and Dr. George D. Fuller, of the University of Chicago, have been engaged in a study of the dunes of Lake Michigan and have an extended publication on this subject in preparation. The younger dunes near the south end of the lake are the ones that have heretofore received the closest study, whereas the present investigation has been largely among the older stabilized dunes of the northern shores of the Michigan side of the lake, some of which bear the highest type of mesophytic forest.

In continuation of the series of bulletins on the trees of the Rocky Mountain region, Mr. George B. Sudworth has issued a treatment of the pines (Department of Agriculture, Bull. 460) similar to that of the junipers and cypresses which appeared some months ago. Fourteen species are described and illustrated and small maps are given showing their geographical ranges.

John Wiley and Sons announce the appearance of a second edition of Dr. Henry Kraemer's Applied and Economic Botany. This book is designed for use in technical and agricultural schools, and for students of pharmacy, medicine, and the chemistry of foods.

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SCIENCE

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THE PENTOSE SUGARS IN PLANT METABOLISM

H. A. SPOEHR

Desert Laboratory, Tucson, Arizona

There is no group of problems more urgent of investigation and pregnant with far-reaching and practical results than those dealing with the more intricate phases of plant metabolism. It is high time that the realization be more generally gained that all products derived from plants, be they sugar, rubber, alkaloids or essential oils, are the result of metabolic activity, and that the study of the mode of formation and increase of these substances is essentially a chemical problem. It is only by means of the most thorough and painstaking investigations, and the employment of the most advanced chemical technique and interpretation that any results in this difficult field can be hoped for.

Of all the chemical substances found in plants the great group of sugars commands the center of attention in considering the various aspects of plant metabolism. All evidence points to the conclusion that sugars are the first products which accumulate in the process of the photosynthetic appropriation of carbon dioxide in the chlorophyllous cell, thus forming the starting point for the syntheses of the tremendous number of substances found in the living organism. The manner in which sugars are converted into fats and how they are incorporated into the complex protein molecules is a problem on which as yet we have but very little information. The courses of many of the other transformations of the sugars still are explained in a purely hypothetical and speculative manner. But not only as synthetic material are the sugars of importance in the economy of the plant, but especially as sources of energy must they be regarded as of greatest importance in the life of the plant. This latter

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quality is undoubtedly due to the ease and multifarious ways in which the sugars are dissociated as well as to their high free energy. Thus, under aerobic conditions the sugars are easily oxidized, and yield a large amount of energy, while under anaerobic conditions also, thanks to their great dissociation, they may undergo chemical changes liberating much energy.

In this respect neither the fats nor proteins can be compared with the sugars as to usefulness for the organism. It is evident therefore that the starting point for a rational study of the chemistry of plant metabolism, as well as of the organic constituents of protoplasm, is the investigation of carbohydrate synthesis, rearrangement and disintegration.

The carbohydrates found in plants are in general of two kinds: those in which there are five carbon atoms, the pentoses, and those containing six carbon atoms, the hexoses. Members of the tetrose series, four carbon atom sugars, are exceedingly rare. The pentoses and hexoses appear to some extent in the monomolecular form, but especially as di- and polysaccharides in which a number of pentose or hexose molecules are condensed to form a large molecule as cane sugar, starch and cellulose. The pentoses are most familiar as pentosans as components of the cell walls and vessels of the plants, and as found in various gums in the form of xylan and araban.

While widespread in the vegetable kingdom, they have but recently been regarded in their important bearing, and, in fact, were for a long time not recognized as belonging to a separate group. These sugars occur mainly in the condensed form as pentosans. In fact, the presence of monosaccharide pentoses has been but very recently established. The main point however, is that the five carbon atom sugars have been found in one form or another as a component of almost all plants.

On account of their great similarity in chemical composition and reaction, the quantitative separation and individual determination of the hexose and pentose sugars is associated with considerable difficulty, and only by the exercise of great care can reliable data be obtained. It has been found that pentoses especially in small quantities can be determined accurately only by first removing all the hexoses by fermentation.[1]

The proportion in which these two groups of sugars appear varies greatly in different plants, some containing no pentoses at all; while in others, such as the platyopuntias at times over half of the total sugars present are pentoses.

On account of their direct economic value and their great importance in animal nutrition, fermentation, etc., special attention has been paid to the hexoses and the chemistry and physiological rôle of this group has been extensively studied. When dissolved in pure water these monosaccharides are comparatively stable substances. Recently it has been found, however, that even small traces of other substances, such as inorganic salts, acids or alkalies in solution induce profound changes. These investigations have aided greatly in an understanding of the manner in which the sugars are rendered so exceedingly unstable and capable of such multifarious reactions in protoplasm and have thrown much light on the causes of the instability of living matter. For example, an aqueous solution of dextrose is barely affected by the oxygen of the air, if however, a trace of an iron salt or of a caustic alkali is added to the solution, oxidation takes place rapidly and with the evolution of much heat. This, very briefly stated, is due to the fact that sugars are actually weak acids, capable of salt formation, that these sugar-salts are far more reactive than the sugars themselves and in aqueous solution spontaneously decompose into smaller molecules capable of oxidation, rearrangement and condensation.[2]

The number of products of such a decomposition is enormous and the nature of the oxidation reaction depends upon temperature, concentration, the inorganic salts present, etc.

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[1] The complete methods and results as well as a more extensive discussion of this subject are to appear in a publication on "The Carbohydrate Economy of Cacti" now in preparation. See also: W. A. Davis and S. O. Sawyer, The estimation of Carbohydrates, IV. The presence of free pentoses in plant extracts and the influence of other sugars on their estimation. Jour. Agri. Sci. **6**: 406–412, 1915.

[2] Nef, J. U., Dissoziationsvorgänge in der Zuckergruppe. Ann. d. Chem. (Liebig) **357**: 214, 1907; **376**: 1, 1910; **403**: 294, 1913.

In these reactions the inorganic salts play the rôle of enzymes, and in all probability enzymes act by virtue of their ability to form salts with sugars. Even in these relatively crude experiments great differences in the reactions of the various sugars appear; it is therefore not surprising that the far more delicately adjusted enzymatic reactions should exhibit large variations in the reactivity of the various hexose and pentose sugars.

That the pentoses are of great physiological importance to the plant becomes evident in the light of recent investigations on the chemistry of the cell nucleus.[3] Among the chief components hereof are the so-called nucleic acids. These are highly complex substances consisting roughly of a combination of phosphoric acid, purines, pyrimidines and several carbohydrate groups. While in the nucleic acids of animal origin the carbohydrate is a hexose, the plant nucleic acids so far studied have been found to contain the pentose group. The function and fundamental importance of the nucleus in the metabolism of the plant need no further discussion here; however, a more intimate knowledge of the chemical composition and action will undoubtedly lead to a clearer understanding of the intricate reactions of this most important organ.

As a further illustration of the rôle of pentoses in the more intricate metabolism of certain plants the relation of these sugars to rubber and terpene formation is of special interest. Harries[4] in his extensive investigations on the constitution of para-caoutchouc has shown that this substance is made up of a large number of groups which have been condensed or polymerized to form an exceedingly large molecule. These individual groups have the composition, C_5H_8, and thus rubber can be considered as being composed of a number of these groups in a similar manner as we think of starch and cellulose as a multi-anhydride of glucose. As the sugars are the first products of the primary organic synthesis in the plant practically all other organic substances found therein must be derived from them more or less directly. Harries considers the C_5H_8 groups as reduction products of the pentoses, ($C_5H_{10}O_5$) and that subsequently the C_5H_8 is condensed to the rubber-hydrocarbon ($C_{10}H_{16}$)x.

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[3] Levene, J. and W. Jacobs, Ber. d. deutsch. chem. ges. **43**: 3147, 3164, 1910.

[4] Harries, C., Ber. d. deutsch. chem. Ges. **38**: 1195–1203, 1905.

Reducing actions are by no means uncommon in plants, especially as the products of intra-molecular respiration and special types of fermentation. A well known example of the formation of a hydrocarbon is the production of methane from cellulose and pentosans by an anaerobic bacillus.[5]

Harries' conception is further substantiated by the fact that the degradation of caoutchouc yields levulinic acid and levulinic aldehyde which are the same products yielded by the sugars.

In the light of the foregoing it seemed therefore not without interest to determine whether a plant which is actually producing rubber would show a condition of its carbohydrate content which might tend to substantiate this theory. The desert rubber plant, guayule, (*Parthenium argentatum*), offered excellent material for such an investigation. The analyses show that in the youngest parts of the plant, in which the rubber is being formed, an unusually high percentage of the total sugars is in the form of pentoses. To the terpenes and their almost innumerable derivatives belong many of the most important plant products, more especially many of the essential oils, camphor derivatives, etc.

The pentoses have been known for a long time to be common components of the walls and vessels of plants. The several attempts at making alcohol on a commercial scale from wood have not been very successful, apparently because a considerable percentage of the sugar produced by hydrolysis of the wood is unfermentable. The constitution of cellulose, however, has not yet been clearly established and the way in which the pentose molecule is united with the other sugar groups is still unsettled.

It has long been known that when starch is hydrolysed all of it does not go over into glucose, as is commonly supposed, but there always remains an unfermentable residue. The nature of this residue has been the subject of repeated investigation without however a definite solution having been reached. There is no doubt, however, that starch contains varying quantities of pentoses. This is a fact[6] which apparently has been disregarded in most of the studies on the constitution of starch, but which certainly must be of greatest importance in the study of the metabolic relations of starch and the other carbohydrates.

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[5] Omlianski, W., Zentr. Bakt. II, 8, 193, 1902. Koch, Jahresber, **14:** 457, 1903.

The question then naturally arises; is starch really of fixed constitution or is it rather of a heterogeneous nature? Undoubtedly glucose predominates in its products of hydrolysis. But glucose usually also is present in largest amounts in the plant juices; it does not seem unreasonable to suppose therefore that when the carbohydrates are laid down this sugar should predominate. Could it be that starch is a form (a physical form) in which the various sugars are laid down for storage and that the pentoses should be included herein? If this were so it could be expected that any of the sugars when presented to a starch-free leaf would produce starch therein. It has been shown that this is the case with all the fermentable sugars. Cremer and Bokorny got doubtful results with l-arabinose and l-xylose.

The writer placed leaves of *Ampelopsis quinquefolia* which had lost all their starch (by being kept in the dark) on solutions of 1% and 2% pure l-arabinose (m.p. 160°) in distilled water. After having been kept in these solutions for two days in the dark, the chorophyll was dissolved out by means of hot 80% alcohol, and the leaves were tested for starch with alcoholic iodine and with chloralhydrate and iodine. The results were unmistakable; along the main veins and 1 to 2 mm. to either side, the dark blue color of the starch-iodine was visible.

Of course, from this experiment it cannot be concluded definitely that the l-arabinose went directly to form starch in the leaf, for there are other substances (e.g., glycerine) which also form starch in the leaf, and we are certain that these are not directly appropriated. In view of the foregoing, however, the experiment is suggestive, and does indicate that this sugar is utilized in the metabolic processes of the leaf. Careful analyses of starches from various sources and formed under known conditions would be desirable information. Similar experiments have been made in order to determine whether the pentoses form glycogen in the liver. The results of various investigators, however, are somewhat contradictory; some having observed an increase of glycogen or pseudoglykogen[7] others reporting entirely negative results. On critical examination of all the experimental data it becomes evident, however, that in several of the cases where negative results were reported the means employed to reduce the glycogen in the liver were such as to affect a more drastic metabolic disturbance than would be compatible with normal conditions.

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[6] Winterstein, E., Ber. d. deutsch. Chem. Ges. **25**: 1237–1241, 1892.
Lintner, C. J., Zeit. angw. Chem. **11**: 725–729, 1898. Chem. Zentr. **62**: II, 732, 1891.

It is evident then, that the five carbon atom group of sugars is a common component of plants, and is of great importance in some of the most vital metabolic activities of the organism. Nevertheless, the origin and mode of formation of the pentose sugars is still quite obscure. This problem is of special interest because any light thereon would be of great value in gaining a clearer understanding of the process of the photosynthetic appropriation of carbon dioxide by the chlorophyllous leaf. The question resolves itself into whether the pentoses are direct products of photosynthesis or are derived from other sugars through subsequent metabolic activity. If for instance, the formation of sugar in the green leaf actually takes place by means of a progressive addition of six molecules of formaldehyde the presence of pentoses is to be expected.

$$2\,CH_2O \rightarrow C_2H_4O_2;\ C_2H_4O_2 + CH_2O \rightarrow C_3H_6O_3;\ C_3H_6O_3 + CH_2O \rightarrow C_4H_8O_4;\ C_4H_8O_4 + CH_2O \rightarrow C_5H_{10}O_5;\ C_5H_{10}O_5 + CH_2O \rightarrow C_6H_{12}O_6$$

If, again, the sugars are formed by the union of two molecules of glycerine aldehyde, hexoses or their condensation products would be the only substances formed:

$$2\quad CH_2OH.CHOH.CH:O \rightarrow CH_2OH(CHOH)_4.CH:O$$

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[7] Cremer, Ergebnisse der Physiol. 11: 898, 1902. Jahresber. f. Fortschritte der Tierchem. 38: 446, 1908.

This, however, is purely chemical speculation and so far has aided little in the solution of the problem of photosynthesis, the real course of which is probably far more complicated than has been generally assumed. Not enough work has been done with the chlorophyllous leaf to draw valid conclusions, and this in turn has been due to the fact that the methods of separation and determination have not been sufficiently delicate and accurate to permit their application to such sensitive material. Most of the work on the pentoses in plants has been done by means of a method which has recently been found to be quite inadequate and liable to yield erroneous results. That is the method depending upon the formation of furfural from pentoses without a previous separation of the other sugars.[8] Also little attempt has been made to distinguish between the soluble monomolecular pentoses and the condensed pentoses present in the plant as pentosans in the cellulose, slimes and gums. For these reasons the question relative to the origin and function of this group of sugars must be considered as not yet definitely answered in spite of the considerable work which has appeared on the subject.

Chalmont,[9] Tollen,[10] Windish and Hasse[11] come to the conclusion that pentoses are formed from hexoses as first products of oxidation that they are relatively inert and probably are of the nature of waste products. This is based essentially upon their observations that the total pentosan content of seedlings germinated and grown in the dark increases with age. The writer made determinations of the total pentoses in seedlings; the results are quite the reverse, however. Wheat seeds were allowed to germinate on glass wool in the dark; at intervals a number of seedlings were removed, dried, ground, hydrolyzed with 1%

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[8] Davis, W. A., and G. O. Sawyer, l. c.
Kluyver, J., Biochemische Suikerbepolingen. Leiden. 1914.
Cunningham, M. and C. Dorée, Biochem. Jour. **8**: 438–447, 1914.

[9] Chalmont, Amer. Chem. Jour. **16**: 218, 589, 1894. Ber. d. deutsch. Chem. Ges. **27**: 2722, 1894.

[10] Tollens, Chem. Zentr. **69**: II, 967, 1898.

[11] Windish and Hasse, Chem. Zentr. **72**: II, 1098, 1901.

HCl, and after determining and fermentating away the hexose sugars the pentose sugars were determined (see table 1).

Unquestionably many organisms utilize the pentose sugars as sources of energy. In their physiological effects the differences between the pentoses and hexoses are in many cases less than exist between closely related members of either one of the groups. Many bacteria and molds are capable of utilizing pentoses as the only source of carbon while on the other hand, other organisms are quite incapable of doing so. The difference in food value of the various hexoses are well known.

TABLE 1

	DAYS				
	0	1	3	6	8
Dry weight	91.80	63.20	54.00	34.80	21.40
Total hexose sugar Fresh	43.35	25.90	25.10	18.94	9.95
Total hexose sugar Dry	47.50	41.00	46.50	54.50	46.50
Total pentoses Fresh	7.60	6.24	1.75	0.57	0.26
Total pentoses Dry	8.30	3.95	3.24	1.66	0.05

Czapek[12] gives the following values for *Aspergillus niger* in weight of yields:

	mgm.		mgm.
d-fructose	523.7	d-Glucose	477.1
l-Xylose	512.7	l-arabinose	350.0
d-Galactose	489.3	d-Mannose	286.8

The high nutritive value of l-xylose is quite evident, while on the other hand it is well known that the yeasts are quite incapable of utilizing any of the pentose sugars. At the same time it must be remembered that no one of the sugars is universally good nutrient material. For example, as Winogradsky and Omlianski[13] have shown even d-glucose is borne only in very low concentrations by certain nitrate bacteria, and in this connection the recent investigations of Knudson[14] are of great interest.

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[12] Czapek, F., Biochemie der Pflanzen, I, p. 311, Jena, 1913.

[13] Winogradsky and Omlianski, Zentr. f. Bakt., 1899, II, 329–344.

[14] Knudson, L., Cornell Univ. Agr. Expt. Sta. Mem. 9: 1–57, 1916.

Such specific action of enzymes is one of the most complex and subtle questions in chemistry.

Little is known of the rôle of the pentoses in the metabolism of the higher plants. The pentosans in the walls and vessels have been very extensively investigated, but, as has been indicated above very little is known of the origin and physiological rôle of these substances in the plant.

In the mammalian body the pentoses have been found to be about isodynamic in food value with the fats but are not protein sparers as the hexoses are. In carnivorous animals as high as 50 to 60% of the amount fed has been observed excreted in the urine; in omnivorous animals the percentage is less while the herbivorous are capable of utilizing relatively large quantities.[15]

Although physiological work with plants has some advantages over the use of animals in metabolism studies, the former nevertheless is associated with obstacles which are exceedingly difficult to overcome. The non-existence of great functional differentiation, the impracticability of injecting substances, the lack of any but gaseous excreta, and the high synthetic power of almost all plant cells, make the study of the intermediate steps in plant metabolism an exceedingly difficult experimental investigation.

The fleshy joints of the cacti have been found to offer splendid material for various phases of these studies. With the development of new and special methods of analysis it has been possible to gather data which it is believed may offer added light to these important problems. In the experiments here recorded *Opuntia* sp. was used exclusively. During March the new joints develop, these grow quite rapidly, so that within about one month the new ovoid joints have attained their full size of 100 to 125 cm. Apparently the young joints are autonomous very early in their development; when cut from the plant with but a very small portion of the parent joint, and placed with the base in tap water, the young joints grow to full size and develop normally. The analyses are given in table 2 in terms of the per cent of the dry material. The first young joints were 2 to 4 cm., about fifteen days old. It is evident that the amount of pentose sugar is considerable even in this very early stage, although the proportion to the total sugars is somewhat higher in the parent joints.

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[15] Schirokich, P., Biochem. Zeit. **55**: 370, 1913.
Magnus-Levy, Oppenheimers Handbuch der Biochem, IV, **1**: 399.

TABLE 2

The carbohydrate content of young and mature Opuntia *Joints. Values given in percentages of the dry material*

DATE	JOINTS	DRY WEIGHT	TOTAL SUGARS	TOTAL PENTOSE SUGARS	PENTOSE TO TOTAL SUGARS	MONOSACCHARIDES	CELLULOSE	ASH
March 27	Young	14.35	31.22	6.23	0.199	2.74	7.24	6.88
	Parent	18.62	22.44	5.21	0.232	3.22	11.35	12.60
April 3	Young	12.70	33.60	9.57	0.285	3.37	6.96	7.51
	Parent	18.90	20.18	10.04	0.495	5.32	11.86	14.40
April 16	Young	11.60	36.68	7.48	0.204	4.43	7.22	10.71
	Parent	18.22	28.40	5.23	0.185	5.00	12.08	13.95

An analysis made in October comparing the young joints, then fully matured, with joints three years old show that there

TABLE 3

Carbohydrate content of young and old joints of the same plant

JOINTS FORMED IN	DRY WEIGHT	TOTAL SUGARS	TOTAL POLYSACCHARIDES	TOTAL HEXOSE SUGARS	DISACCHARIDES	HEXOSES	TOTAL PENTOSE SUGARS	PENTOSES	PENTOSAN	TOTAL SUGARS TO TOTAL PENTOSE	CELLULOSE
1916	17.85	20.45	17.94	10.10	1.18	1.27	9.78	0.23	9.55	0.478	9.10
1913	20.11	16.60	14.45	9.10	0.51	1.22	7.10	0.40	6.70	0.428	10.26

TABLE 4

Daily variation in carbohydrate content of Opuntia sp. *in October*

	DRY WEIGHT	TOTAL SUGARS	DISACCHARIDES	HEXOSES	TOTAL PENTOSE SUGARS	PENTOSANS	PENTOSES	TOTAL SUGARS TO TOTAL PENTOSE
5.00 p.m.	17.58	16.18	0.58	1.06	8.60	8.34	0.26	0.531
7.30 a.m.	18.80	19.40	0.34	0.83	8.33	8.22	0.20	0.430
5.00 p.m.	17.85	20.45	1.18	1.27	9.78	9.55	0.23	0.478

is no accumulation of either pentose sugars or of pentosans in the old material. In fact, in several other determinations the proportion of pentose sugars in the young was slightly higher than in the old joints. There is, therefore, no evidence here which supports the opinion that pentoses and pentosans are end or waste products which accumulate in the older portions of the plant.

In the cacti the daily variation in the carbohydrate content is slight. Davis, Daish and Sawyer note that the pentoses and pentosans rise steadily during the night in the mangold leaf (mangel wurzel). This was not observed in the cacti, but rather a slight diminution of these sugars during the night.

During the course of the year there is considerable variation in the total carbohydrate content of the cactus as well as in the proportion of the various kinds of sugars. These variations are the result of environmental influences; especially the amount of available water and temperature. A rational conception of the carbohydrate metabolism of a plant can be gained only through the study of the equilibrium of the various sugar components and the factors which influence these equilibria. This paper is confined to a brief consideration of the pentose sugars. These show a decided increase both in actual amount and in the proportion to the total sugars as the water content of the plant decreases. In table 5 are given the results of monthly analyses of joints of *Opuntia* sp. of the same age and from the same plant growing out of doors.

The first analyses were made during the dry fore-summer—the pentose and hexose sugars are present in about equal proportion. The summer rains began the middle of July and continued through August. During this period of rain the total sugars are reduced, and especially the pentoses, bringing the proportion of hexose sugars considerably higher.

September, October and November were very dry months (less than 1 inch rainfall) with a little rain to December 20. The increase in pentoses during these dry months is very noticeable. There was regular rainfall during the last week in December and January. The March samples were taken a few days after a rain, thereafter the dry fore-summer conditions set in. The effects of these periods of rainfall on the relative sugar content and especially on the pentoses are striking. Changes in temperature also affect the equilibrium, and—as separate experiments have shown—in such a manner that at higher temperatures the proportion of monosaccharides is reduced in favor of the polysaccharides. However, this applies particularly to the hexose sugars, the effect of temperature on the pentose-pentosan equilibrium is slight.

TABLE 5

Seasonal variations in sugar content of Opuntia sp.

	DATE										
	July 5	July 31	September 20	October 27	November 15	December 20	January 11	February 16	March 17	April 25	May 22
Dry weight....	36.38	16.45	19.66	20.30	23.05	30.10(?)	22.20	22.33	19.50	24.30	25.25
Total sugars...	20.03	13.24	18.44	20.90	18.75	18.95	19.10	21.32	28.05	32.40	30.15
Total hexose sugars.......	10.45	8.60	8.83	9.32	5.50	7.90	14.95	14.90	22.16	22.70	17.08
Total pentose sugars.......	9.26	4.39	9.08	10.95	12.50	10.45	4.73	6.07	5.55	9.15	12.34
Pentosans.....	9.04		8.86	10.47	11.35	10.10	4.40	5.51	4.75	8.68	12.17
Pentoses......	0.20		0.24	0.48	0.82	0.35	0.43	0.55	0.82	0.48	0.16
Total pentose sugars to total sugars.	0.462	0.332	0.492	0.524	0.667	0.551	0.248	0.283	0.198	0.283	0.409
Total hexose sugars to total sugars.	0.522	0.650	0.479	0.446	0.293	0.417	0.783	0.698	0.791	0.702	0.567

It was possible to reproduce experimentally the effect of the water content on the pentose sugars. Two sets of Opuntia joints, taken from the same plant, under identical conditions were placed in a dark room at constant temperature, 28°. One set (A) was kept with the base of the joints in water, the other set (B) was kept dry; the experiment continued for a month. (A) produced a few small roots, 5 to 10 cm. long, the water was tested from time to time, but not a trace of sugar could be detected. The results are given in table 6.

TABLE 6

The effect of the water content upon the proportion of total pentose sugars

	DRY WEIGHT	TOTAL SUGARS	TOTAL HEXOSE SUGARS	TOTAL PENTOSE SUGARS	TOTAL PENTOSE SUGARS TO TOTAL SUGARS	TOTAL HEXOSE SUGARS TO TOTAL SUGARS
A	16.34	8.29	6.70	1.50	0.181	0.808
B	23.25	11.90	6.36	5.22	0.439	0.534

It is highly probable that this fact explains the observation of various workers that the total pentoses increase with advancing age of the plant, as in general the water content decreases as the plant grows older. Unfortunately, however, in these older investigations no data are given concerning the amount of water. Furthermore, in using the old methods the cellulose of the walls and vessels is usually also hydrolysed; this fibrous material increases with age in the plant and is known to contain a high percentage of pentose. The fact that the pentose sugars tend to disappear with increasing water content is of special interest in considering the theory previously mentioned of the formation of rubber from pentoses in the rubber plants.

In the commercial culture of these plants the effect of water is best expressed in a proverb used by the Mexicans of the Guayule rubber country: "much water, little rubber."[16] This, of course, must be regarded as rather circumstantial evidence in favor of the pentose origin of rubber.

The salient feature of these experiments is that the pentose sugars accumulate only under conditions of low water content. Little light is thrown on their origin. While Davis, Daish and Sawyer in the mangold leaf observed a rise in the pentoses apparently at the expense of the hexoses, the large number of experiments with cacti are not univocal herein. The problem, however, is very complex involving factors some of which are impossible to control.

The course of carbohydrate consumption during starvation of joints of *Opuntia* sp. throws some light on the utilization of the various sugars. A large number of joints of the same age and cut from the same plant were kept in the dark at a constant temperature, 28°. It is a very striking fact that although the joints are constantly losing water through transpiration, the water content after about the first month remains fairly constant.[17] Thus also the proportions of the various sugars to each other maintain a surprising regularity as the depletion proceeds; hexose and pentose sugars are consumed at about the same relative rates (table 7). It is quite evident that not only is there no accumulation of pentoses but these sugars are used up at a very appreciable rate.

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[16] From a private communication of Dr. W. B. MacCallum.

TABLE 7

The course of carbohydrate depletion during starvation of Opuntia sp.

	DATE					
	December 20	February 12	March 2	March 22	April 20	May 12
Dry weight	31.50	36.80	36.20	40.13	40.50	37.60
Total sugars	22.86	16.62	13.71	15.23	14.54	13.52
Total polysaccharides	20.38	14.22	12.30	14.10	13.52	12.46
Total hexose sugars	19.74	14.85	12.25	13.27	12.24	11.70
Hexose polysaccharides	17.64	13.72	11.15	12.41	11.48	10.87
Disaccharides	1.63	0.72	0.73	0.70	0.55	0.59
Hexoses	0.62	0.49	0.45	0.21	0.26	0.30
Total pentose sugars	2.93	1.68	1.38	1.84	2.17	1.72
Pentosans	2.67	1.33	1.08	1.55	2.02	1.50
Pentoses	0.36	0.34	0.30	0.25	0.15	0.22
Monosaccharides	0.98	0.83	0.75	0.46	0.31	0.52
Monosaccharides to total polysaccharides	0.048	0.058	0.061	0.033	0.023	0.042
Total pentoses to total sugars	0.128	0.101	0.101	0.121	0.149	0.127

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[17] Mac Dougal, D. T., E. R. Long and J. C. Brown, End results of the desiccation and respiration in succulent plants. Physiol. Res. 1: 289–325, 1915.

THE VEGETATION OF CONGLOMERATE ROCKS OF THE CINCINNATI REGION

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On the limited areas of conglomerate rock within the Cincinnati region, is a vegetation so unique for this region, so different from all the surrounding vegetation, that it has no place in the major plant formations of the region. On these rocks there is an independent succession in progress which only in its latest stages, begins to merge with the surrounding associations.

Location and extent of rock outcrop. Conglomerate rocks in the Cincinnati region are exposed mostly in the little Miami valley, and in that part of the Ohio valley just above the mouth of the Little Miami river. A few areas also are found in the Miami valley. The outcrops occur in groups, so that there is usually a number of outcrops very close together. These groups or areas may be several miles apart. Rock exposures vary from a few square feet to hundreds of square feet in area. All the outcrops are found on hillsides where there are remnants of glacial terraces.

Origin of the conglomerate. The conglomerate was made by the cementation of outwash gravels of the Illinoian and Earlier Wisconsin glacial stages. In most of the Cincinnati region, these gravels—especially those of Wisconsin age—are loose and unconsolidated, or only partially cemented. In places they have been so well cemented as to form a very firm and resistant conglomerate.

Composition and texture. The pebbles and bowlders of the conglomerates are of various materials—limestone, quartz, and igneous rocks. Limestone everywhere predominates so that the rock may be considered a limestone conglomerate. The cement is calcareous, locally ferruginous. The texture of the rock varies from a coarse conglomerate to a sandstone with few pebbles. Within the same rock mass, the gravel varies greatly in size, from particles the size of coarse sand grains to bowlders several inches in diameter.

The larger bowlders are embedded in a matrix of smaller particles. The rock is extremely porous. The weathered surface is very irregular due to numerous projecting bowlders, and to small depressions or pockets formed when bowlders weather out.

Comparison with bed-rock of region. The conglomerates of the Cincinnati region everywhere tend to be more massive than the bed-rock. Because of this there is a difference in the manner, possibly also in the rate of weathering of the two types of rock. Weathering of the conglomerates is due to the action of surface agencies and ground water, resulting in the gradual reduction of surface, with the accompanying formation of soil on the rock surface, and the occasional loosening of surface bowlders. In the weathering of bed-rock, there is, in addition to the above factors, a pronounced sapping of limestone layers due to the rapid disintegration of the interbedded shales. This results in sudden and relatively great changes in the surface of the rock exposed, and yields instead of fine soil, numbers of large slabs of limestone which are relatively soon covered with soil from the surrounding slopes. Decomposition is more effective in the weathering of the conglomerates than is disintegration. In the case of the bed-rock the reverse is true. The hillside around the conglomerate rock is frequently reduced to a fairly gentle slope from which the rock mass projects. For this reason, the conglomerates usually project as huge masses from the hillside (fig. 1).

ECOLOGICAL FACTORS

Moisture. Except during and for a short time after rains, much of the surface of these rocks is dry. Some water is held for a time in the surface pockets. The accumulation of soil in the pockets, and the deep moss mat are important in lessening run-off. The irregularities of the surface and the porous nature of the matrix, facilitate the entrance of rain water. The fine-grained parts of the masses serve as reservoirs to retain and gradually feed out the water after the surface portions become dry. Part of the rock, too, is buried deep in the soil of the hillside where there is always a constant supply of moisture.

The amount of water available to the vegetation of these rocks depends directly on the steepness of slope of the surface and on the texture of the material, and indirectly on the direction of slope.

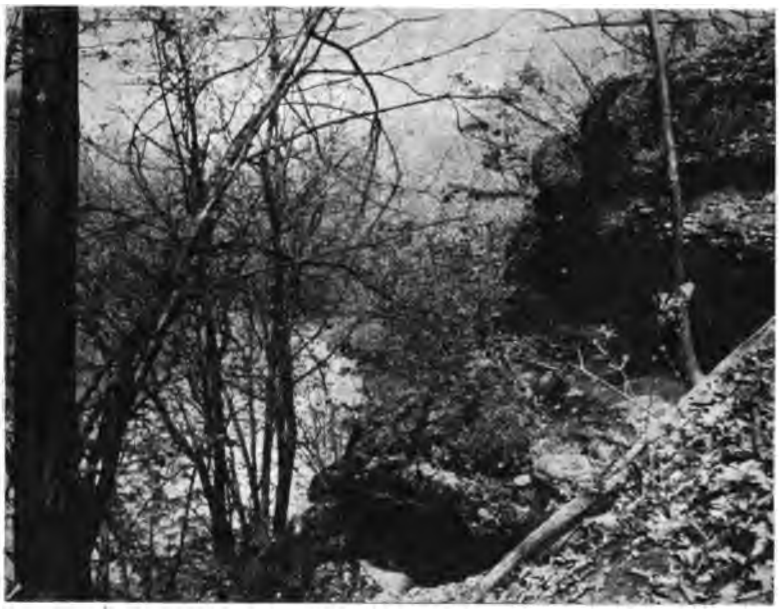

Fig. 1. Conglomerate rock outcrop on hillside; patches of moss and Sedum are prominent, with shrubs on the ledges.

The influence of steepness of slope is seen in the distribution of plant communities (fig. 4). We find the most xerophytic communities on the vertical faces and edges of shelves, the xero-mesophytic communities on gently sloping and irregular parts of the rock, and the most mesophytic communities in deep and sheltered angles where both surface water and water drain-ing from the rock pores is collected. A few places are almost constantly wet, due to a gradual seepage of water from the interior of the rock.

Direction of slope is important because of differences in exposure to sunlight resulting in differences in evaporation (figs. 4 and 5). The effect is indicated in the progress of the plant successions and the character of the final closed associations found on different slopes. The texture of the rock material determines the volume of water which may be held in the pores of the rock, and the rapidity with which water may enter from the outside.

Measurements of the water content of small pieces of the conglomerate from the surface of the rock mass showed an average of 4.45 grams water to 100 grams dry weight of rock.

Rock weathering. The character of the weathering of these Pleistocene conglomerates—slow surface decomposition without sapping—is probably the most important factor in determining the nature and completeness of the marked plant succession on these rocks. It is chiefly because of this physical characteristic of the habitat that the very marked plant communities are developed.

Soil. As a result of rock weathering and plant decay there is accumulated in the irregularities of the surface, a very black sandy humus. This soil is strongly calcareous, due to the presence in it of numerous minute grains of limestone produced by the disintegration of the conglomerate upon decomposition of its cement. The soil is extremely light, fine grained, and spongy when wet, and does not bake on drying. The average capillary water content as determined from a number of tests is 62.26 grams water to 100 grams of air dry soil.

Isolation. Isolation of any area is an ecological factor because of the effect on plant distribution. Outcrops or groups of outcrops of conglomerate rocks are frequently several miles apart. The intervening space is forest, cultivated, or waste land, usually having little in common with the rock habitat.

Outcrops of the limestone and shale bed-rock of the region are seen (1) along stream banks, (2) in ravines, (3) in quarries, and (4) occasionally near the tops of the higher hills. Slabs of limestone weathered out from the bed-rock are numerous on the steeper hillsides. In the first two types of locations, the rocks are subjected usually several times annually, to the erosive action of streams. In the third type, conditions of light and moisture are extreme, especially in those quarries recently worked. When the quarry has been long abandoned, the face is almost covered with soil and small rock fragments, thus giving adequate foothold for herbaceous and even tree growth. The fourth type of location, rock outcrops near the tops of the higher hills, is somewhat similar to the conglomerate outcrops under consideration. Even here, the rock succession[1] is very incomplete, only the earliest lichen and moss stages being represented before the advent of herbaceous and woody plants, which appear relatively early because of the many crevices. Because of the position, high up on slopes, the rocks are always exposed to direct sunlight, until shaded by their own vegetation. The limestone slabs lying on the surface of steeper hillsides are so small that they can only support a very meager flora.

The character and frequency of rock outcrops in the Cincinnati region has been given here in order to make clear the degree of isolation of the conglomerate rock areas in the region. The vegetation of these rocks is of interest chiefly because of its unusualness in the region. It is of a character to be expected in a rocky region, where migration from area to area is easy. It is remarkable in a region of few stable rock outcrops, where distance becomes an obstacle to migration.

VEGETATION

The plant succession of the conglomerate rocks of the Cincinnati region is the only typical rock succession in the region. The succession passes through various lichen and moss stages before the advent of herbaceous and shrub stages.

1. *Lichen stages*. The lichen stages of the succession are two

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[1] Braun, E. Lucy. The Physiographic Ecology of the Cincinnati Region. Ohio Biol. Survey, Bulletin 7, 1916.

in number, one dominated by crustose lichens, the other by foliose lichens.

The first or crustose lichen stage is seen on the smoother and more exposed rock faces. The patches of crustose lichens are separated by spaces of bare rock, or rarely nearly cover the surface. The lichens most commonly found are *Lecidea sp.*, *Pertusaria communis*, *Staurothele umbrina*, *Verrucaria muralis*, and *Placodium citrinum*. With these crustose lichens, but of only minor importance in this lichen community, is the xerophytic moss, *Grimmia apocarpa*. Foliose lichens begin to appear early in the crustose lichen stage, but reach their culmination only on partially shaded rocks.

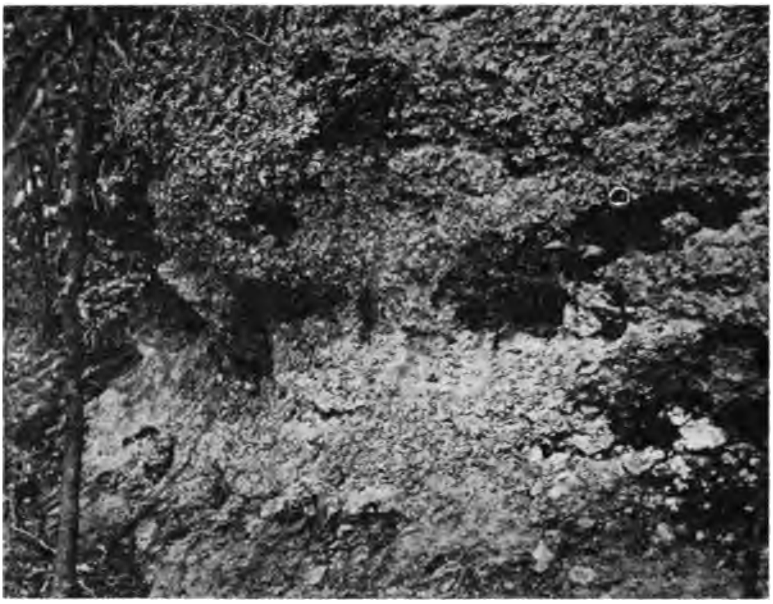

Fig. 2. The foliose lichen, *Dermatocarpon miniatum*, on steep rock surface facing S25° W; scattered herbaceous plants in pockets. Both transects, figures 4 and 5, cross this area.

The second or foliose lichen stage is dominated by *Dermatocarpon miniatum*. Where best developed the large gray thalli of this plant nearly cover the rock surface (fig. 2). A few secondary species of lichens are present, most prominent of which is the gelatinous lichen, *Omphalaria sp.* Mosses become more important, both in numbers and species, than in the crustose lichen stage. *Grimmia apocarpa, Anomodon attenuatus,* and *Leskea sp.* are represented, and in places become so abundant as to interfere with the lichens, thus indicating the next stage in the succession. The aspect of the foliose lichen stage changes from place to place. *Omphalaria* is sometimes the facies of the association. In places the foliose lichens are not well represented, and the mosses of this stage assume greater prominence, though scarcely more abundant.

Fruticose lichens are entirely absent from the succession, which in this respect differs from rock successions described elsewhere.[2]

On the undersides of overhanging ledges and on many rock faces protected from direct light, none of the characteristic lichens of the two preceding stages are seen. In their places, is the pale powdery lichen, *Amphiloma lanuginosum,* and rarely a light green moss, *Plagiothecium* sp. The sharp color contrast between the dull grey-greens of the lichen communities or the dark rich green of the moss mats, with the pale yellowish green of this lichen is often very striking. In very sheltered spots the *Amphiloma* sometimes grows with the mesophytic mosses and occasionally overruns them.

2. Moss stages. The first mosses appear early in the lichen stages of the succession, but it is not until after the foliose lichen stage is well advanced, that they become prominent.

The first well marked moss stage is dominated by *Anomodon attenuatus,* with *Leskea sp., Anomodon minor, Grimmia apocarpa,* and the liverwort, *Porella platyphylla,* as secondary species. Crustose and foliose lichens persist in spots. *Grimmia* is the most xerophytic of the mosses and is really a relict of an earlier stage; *Anomodon minor* seems to be the most mesophytic of the mosses here represented, and indicates an advance to more mesophytic conditions. It is usually found in more sheltered spots or on gentler slopes as a constituent of the ever thickening moss mat.

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[2] Cooper, W. S. The ecological succession of mosses, as illustrated upon Isle Royale, Lake Superior. Plant World **15**: 197–213. 1912.

Cooper, W. S. The climax forest of Isle Royale, Lake Superior, and its development. Pt. II, The successions. Bot. Gaz. **55**: 115–140. 1913.

Fink, Bruce. A lichen society of a sandstone riprap. Bot. Gaz. **38**: 265–284. 1904.

On flat ledges and in sheltered and shaded spots, the mosses of the first stage are replaced by more mesophytic kinds.

A second moss stage, much more mesophytic than the first, becomes evident. This is characterized by a very dense and deep moss mat, in which *Mnium cuspidatum* is the facies, and *Rhodobryum roseum, Catharinea crispa, Entodon seductrix, Brachythecium salebrosum, Fissidens incurvus* and the mosses of the previous stage, except Grimmia, are secondary species. The foliose lichen, *Peltigera apthosa,* and the liverwort, *Conocephalum conicum,* are important locally. The mosses of this stage vary in importance at different periods of development and in different parts. *Mnium*—always characteristic of this community—becomes increasingly important with the development of the succession. The series from *Anomodon* as the dominant plant, to *Mnium* as the dominant is well marked in a number of places.

Beneath the moss mat of this stage there is being accumulated a thick layer of humus, preparing the way for the advent of the herbaceous plants which follow.

3. Herbaceous stages. Herbaceous plants begin to appear as soon as there is some soil accumulated in the irregularities of the surface. The usual distinction between crevice and surface plants is scarcely applicable here. The first herbaceous plants grow in the shallow soil of the pockets, which unlike crevices, do not permit of deep rooting.

With the accumulation of soil in the pockets, and the growth of the moss mat, there begins an open herbaceous stage, which on sunny south rock slopes may telescope the second moss stage. The first herbaceous plants of the pockets appear in the foliose lichen stage (fig. 2). The pioneer herbs are *Aquilegia canadensis* (wild columbine), *Cystopteris fragilis, Woodsia obtusa,* and *Poa compressa.* As the mosses spread over the surface and furnish soil and a foothold for herbaceous plants, the presence of pockets comes to be of less importance. Late in the first moss stage patches of herbaceous plants, among which *Sedum ternatum* is most prominent (fig. 1), begin to compete with the mosses. The most rapid advance of herbaceous plants is made on gentle slopes and ledges.

On southerly slopes and in all dryer situations, the most advanced herbaceous stage seen is a xero-mesophytic closed association in which *Sedum* is dominant throughout the year. With the Sedum, and of varying importance at different seasons, are *Cystopteris fragilis, Aquilegia canadensis, Silene virginica, Aster Shortii, Viola Rafinesquii* and *V. striata, Arabis Drummundi, Heuchera americana,* and a few individuals of a number of other less characteristic plants.

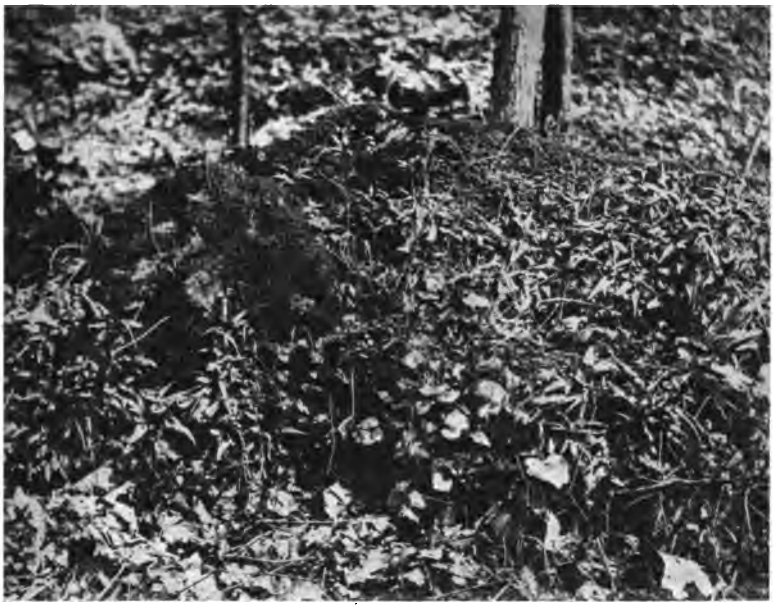

Fig. 3. Walking fern and Mitella on a northward facing moss-covered rock.

On northerly slopes the earlier herbaceous stages are contemporaneous with the lichen and moss stages. Throughout the moss stages the number of herbaceous plants steadily increases.

On north slopes, after a short succession with numerous instances of telescoping, and on east and west slopes, after a much longer and more complete succession, the most advance herbaceous stage of the rock succession is reached. This is a mesophytic closed association dominated by walking fern, *Camptosorus rhizophyllus* (fig. 3). Where best developed, this fern grows in dense tangled masses in a moss mat composed of the mosses of the second or *Mnium* moss stage. With the walking ferns are a large variety of other herbs, most characteristic of which are *Mitella diphylla* and *Cystopteris bulbifera.* Other plants of the association are maidenhair fern (*Adiantum pedatum*), great chickweed (*Stellaria pubera*), rue anemone (*Anemonella thalictroides*), *Corydalis flavula, Cardamine Douglassii,* Dutchman's breeches (*Dicentra Cucullaria*) tall bellflower (*Campanula americana*), and a number of the plants of the preceding stage.

4. Shrub stages. On shelves, on the upper surface of the rocks, and in large pockets wherever several inches of soil have accumulated, are a number of shrubs—bladder nut (*Staphylea trifolia*), gooseberry (*Ribes gracile*), fragrant sumac (*Rhus canadensis*), nine-bark (*Physocarpus opulifolius*), and poison ivy (*Rhus Toxicodendron*) in dry parts, and wild hydrangea (*Hydrangea arborescens*) in damp places. In only a few rock areas, the shrubby plants form definite communities with a well established place in the rock succession. A shrub stage when represented, may follow either of the closed herbaceous associations. The shrubs of dryer parts of the rocks, only one or two of which are usually represented in any one rock area, follow the *Sedum* association (fig. 1). The hydrangea shrub stage is seen only in very moist places, and follows some phase of the mesophytic closed herbaceous association.

Transition to surrounding forest. Only on the tops of the rocks, where the accumulated soil is relatively deep, does the vegetation show any transition to that of the surrounding hillsides. Herbaceous plants of the hillsides, and occasional saplings, grow in the deep soil on the rocks. But the covering of the

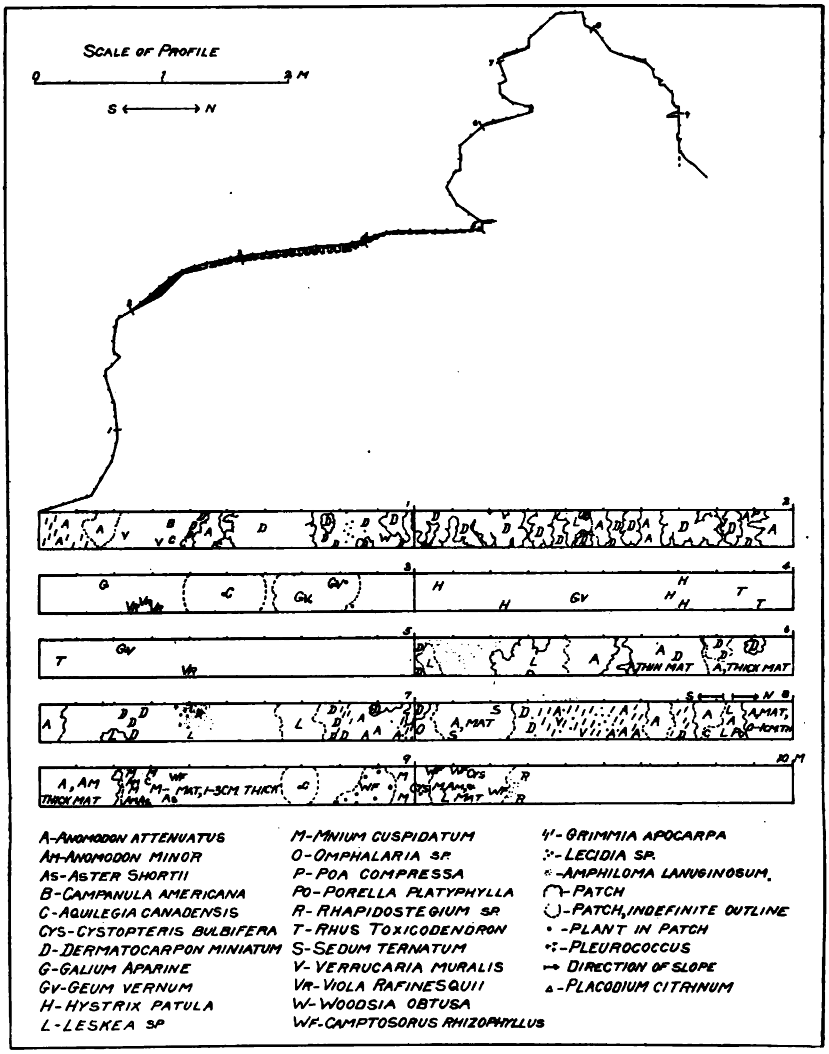

Fig. 4. Belt transect showing relation of vegetation to steepness of slope; direction of slopes, S25° W and N; transect follows rock profile shown above.

rocks by a deep soil, and the consequent appearance of plants from the surrounding forest, does not represent a step in the rock succession, but rather the elimination of the rock habitat, and with it, of its characteristic vegetation.

Effect of slope on vegetation. Throughout the progress of the rock succession, the effect of steepness and direction of slope is very marked. Change in the angle of slope is always accompanied by some change in vegetation. Slopes of the same steepness but of different direction show very great differences in the character of the vegetation. The accompanying transects, figures 4 and 5, illustrate these effects of direction and steepness of slope.

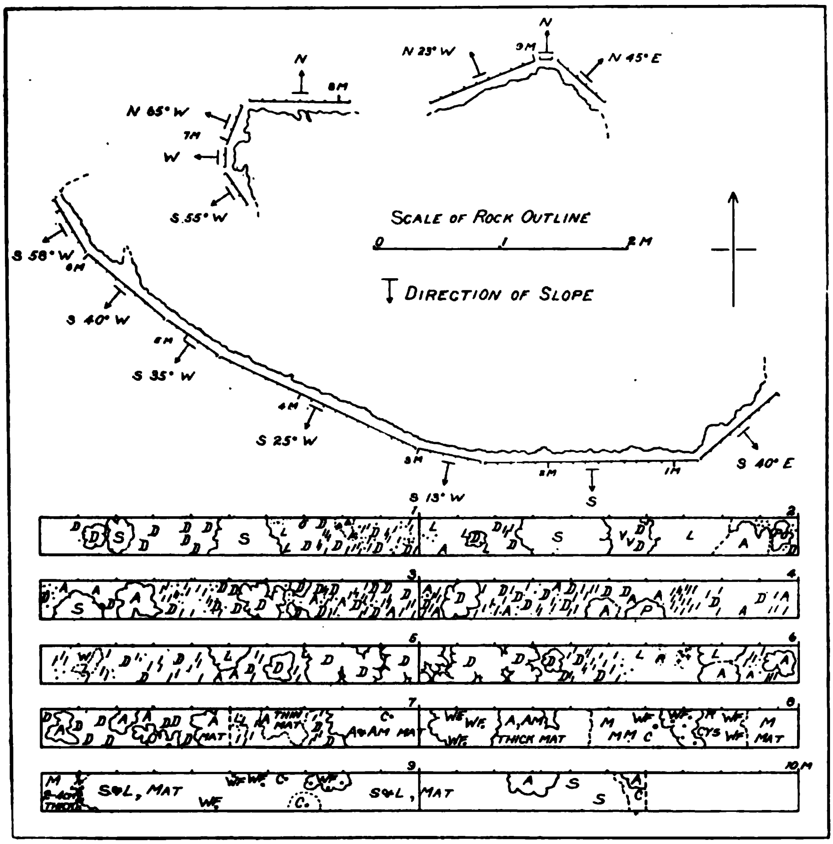

Fig. 5. Horizontal belt transect showing relation of vegetation to direction of slope; angle of slope, 55° to 65°; transect follows rock outline shown above. Abbreviations as in figure 4.

Plants confined to conglomerate rock areas. A few of the plants of the conglomerate rocks are confined to this habitat within the Cincinnati region; others are usually confined to the sandy or gravelly soil of terraces; and still others are of rather general distribution. The most characteristic plants of the various stages are the plants of most limited distribution. *Dermatocarpon miniatum* is known from only one rock area with outcrops at short intervals over a distance of about a mile. Walking fern (*Camptosorus rhizophyllus*) and *Cystopteris bulbifera* are confined to conglomerate rocks within this region. These are characteristic plants of limestone cliffs throughout a wide geographical range, and have been recorded from stations 50 to 100 miles from here, but are not known to occur in the intervening area. Many of the secondary species, and a few of those determining the facies, are of less limited distribution, but by no means general in the region. Thus *Mitella diphylla*, *Woodsia obtusa*, *Aquilegia canadensis*, *Arabis Drummundi*, *Physocarpus opulifolius*, and *Silene virginica* (usually) are confined to the relatively small areas of sandy or gravelly soil within the Cincinnati region.

The vegetation of the conglomerate rocks of the Cincinnati region represents an isolated plant community deriving some of its members from the ordinary vegetation of the region; others from the vegetation of the nearest related soil areas of the region; and still others—the most characteristic elements in this rock succession—are not represented elsewhere in the region, and must have been derived from distant similar habitats.

BOOKS AND CURRENT LITERATURE

Absorption and Secretion.—Even though an enormous volume of experimentation bearing upon absorption and secretion has come from both animal and plant physiologists, some fundamental facts relative to these phenomena are too little understood, as indicated by text books dealing with these subjects and by a number of recent researches. Furthermore, the animal physiologist has failed to familiarize himself with the investigations of the plant physiologist and vice versa, so that there has been in some instances a duplication of effort to no purpose and a failure to coördinate similar problems in the two fields of study. A recent book by Fischer,[1] written by one who has employed animal tissues throughout his investigations, is the most lucid and illuminating account which has ever been written on the subject of absorption and its mirror image secretion, and the relation of these two phenomena to the pathological states called oedema, nephritis, glaucoma, etc. It should be read with equal enthusiasm by both plant and animal physiologist and should be far reaching in its influence in eradicating many misconceptions which are now being promulgated by teachers of physiology. It is idle to suppose that any adequate notion can be given of Dr. Fischer's treatment of the subject in a brief review, but it is hoped by this means to call the attention of physiologists and pathologists to a stimulating and meritorious work whose presence is not generally known to them.

The subject matter of a book on oedema published several years earlier by the same author has been enriched by subsequent experimentation, and he has combined with it his studies upon other pathological states following abnormal absorption or secretion.

He has summarized in the form of a résumé, occupying the first thirty-four pages, his conclusions, based upon observations and clinical data presented in detail in the remainder of the book. His conclusions all center around the view that the absorption of water, whether normal or abnormal, by the living organism is determined by the colloids con-thesia, how salines decrease generalized oedema and relieve uremia, tained in it and their state. The acceptance of this view constitutes a tacit dismissal of the osmotic theory of Pfeffer and De Vries, the lipoid membrane theory of Overton, the mosaic thoery of Nathansohn, and the pressure theory of Pfeffer and his students. All of these theories depend for their operation, upon the presence of a membrane through which water and the dissolved substances pass. Difficulty arises when one attempts to explain by these theories, how both water and dissolved substances move into the cell at the same time or out at the same time, or in opposite directions, either into the cell or out of the cell at the same time, yet this must be possible within living cells. By the theory which regards the protoplast as a colloid-chemical complex, there is no need for membranes about the cells. This colloid complex cannot only absorb and secrete water, but it can absorb and secrete any dissolved substance at the same time, the two processes being directed either in the same or opposite directions. The laws governing hydration and dehydration of lyophilic colloids then govern their absorption and secretion. The differences in concentration within and without the cell can thus be accounted for by differences in solubility, differences in adsorption, and differences in chemical constitution.

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[1] Fischer, Martin H. Oedema and Nephritis: A critical, experimental and clinical study of the physiology and pathology of water absorption in the living organism. Second and enlarged edition, pp. 695, New York, 1915.

The problem of oedema is regarded as dependent upon an increased or heightened hydration of the body colloids and the cause of which increase exists within the tissues themselves. This increased hydration, he maintains, is caused by the accumulation of acids within the tissues, brought about either through their abnormal production, or through their inadequate removal, though some of it may be due to the production or accumulation of substances of the type or urea, pyridin, certain amins, etc., which hydrate colloids as do acids, or even to the conversion of colloids having little capacity for water to those having a greater hydrophylic capacity. The bearing of the problem of oedema in animals to such states in plants as are described as overgrowths, excrescences, galls, cankers, intumescences, crown gall, knots, etc .are not far to be sought. Furthermore, the author's experimental procedure on oedema is such that it could in many cases be duplicated in work of instruction in the classroom and laboratory.

The studies in secretion are for the most part concerned with the kidney but here again many related problems suggest themselves and both the investigator and the teacher will find a lively interest in Dr. Fischer's treatment of the fundamentals of the process. Such interesting vital questions as the reason for a decreased urinary output following anaeswhy blood remains in the vessels, are all included in the problem of secretion and are presented with a body of clinical and experimental data.

FREDERICK A. WOLF.

NATURAL HISTORY OF COSTA RICA.—This is a record of a year's travel, collecting and study of the natural history of Costa Rica, from May 1910 to May 1911.[1] The attention of the authors was especially directed to the insect life of the regions visited. The book is essentially a record of their personal experiences, and is far too much taken up with the details of travel, data of accommodations, and kindred other unimportant incidents common to living and travel in Central America, that may be interesting to the tourist but of no value to the naturalist. The valuable parts of the book are the author's observations upon the life histories, habits and distribution of the organisms studied by them; their data of climate and topography, and their excellent and numerous photographs of plants and animals, especially the insects. There is a conspicuous lack of any broad conceptions of the distribution of the species studied, or of their ecological relations, and the book would have been much improved by some general summary and discussion of the results secured. The observations recorded are valuable, however, and will certainly find their place in subsequent general considerations of the biology of Costa Rica. In this respect the book is a welcome and distinct contribution. Appendices contain a record of the authors' itinerary, with notes upon the "weather," "weather" records at Cartago, bibliography, and a list of the plants and animals mentioned in the text. The book will stand with Belt's A Naturalist in Nicaragua, as a record of observations, but is not the equal of Belt's work in insight into the ecological relations of the organisms studied, and understanding of the problems of tropical biology, and it is hoped that in some subsequent publication the authors will give us this summation of their work.—W. L. TOWER.

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[1] Calvert, Amelia Smith, and Philip Powell. A Year of Costa Rican Natural History. Pp. 577, figs. 137, 5 maps. The Macmillan Company, New York, 1917 ($3.00).

NOTES AND COMMENT

Every day brings fresh evidence of the determination of the United States to win the great war. We enjoy a grim sense of satisfaction in every sacrifice we make that contributes to this end. The scientific men of the country are giving their ripest ideas and their best efforts to aid in the struggle. It must give profound satisfaction to every one of these men, however ardent his patriotism, to realise that we have not yet had in this country an outbreak of the folly of renouncing German degrees, melting German medals, and repudiating scientific literature and generalizations of German origin. We are not engaged in a combat with Intellectual Germany. If there were no other Germany than this there would be no war in progress. It is Political Germany which we are bound to crush, chiefly for the sake of our own political safety. In doing so we may aid in the rescue of Intellectual Germany from the noisome militaristic infections that have sometimes attacked it. A programme of renunciation and repudiation would mar our future relations with Intellectual Germany, would belittle American science, and would contribute nothing toward winning the war.

A text entitled Genetics in Relation to Agriculture is in an advanced state of preparation by Dr. Ernest B. Babcock and Dr. Roy E. Clausen, of the University of California. The work will consist of about 600 pages, with numerous illustrations, glossary and bibliography, and the publishers will be the McGraw Hill Book Company of New York. The first half of the book will treat the fundamental principles of genetics, with an up to date exposition of Mendelism, and chapters on variation, biometry, pure lines and mutations. The second half is devoted to applied genetics, with respect to both plants and animals, and is designed to form a clear and practical exposition for the layman.

On the attainment of his seventieth year, in February, Prof. Hugo De Vries will retire from the professorship of botany at the University of Amsterdam. As a testimonial of their esteem the Dutch botanists are preparing to issue a set of six volumes containing the essays and papers of Professor De Vries which it is now impossible or difficult to obtain. Persons desirous of securing these volumes should communicate with Prof. Theo. J. Stomps, Weesperzijde 29, Amsterdam.

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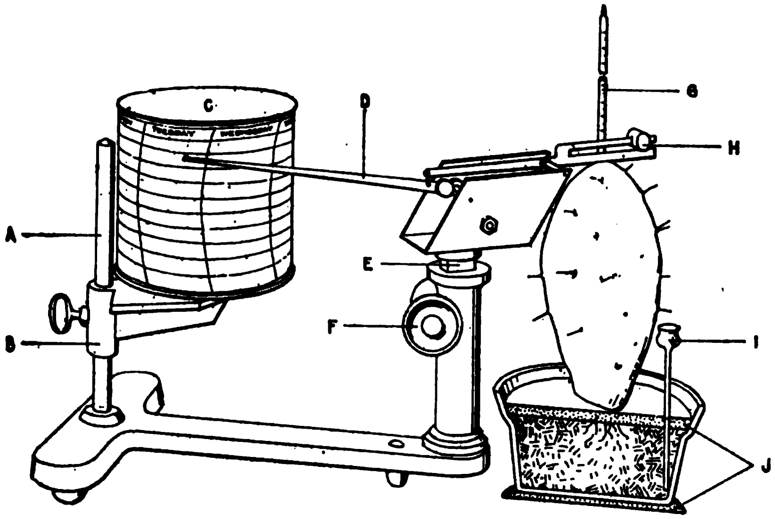

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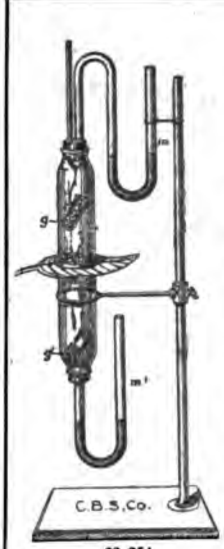

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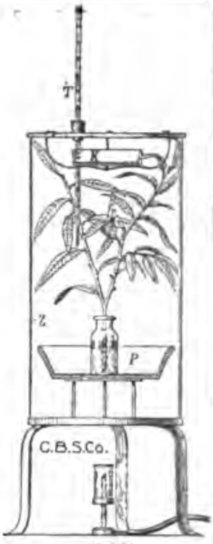

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